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This report identifies meteorological and air quality data sources for the oil shale areas of Western Colorado, Eastern Utah and Southern Wyoming. The information and bibliography identified in this report are not complete, or exhaustive, but consist of the material collected during 1980-1982 as part of the Green River Ambient Model Assessment program. These materials were collected with three criteria in mind: generic information applicable to the oil shale area, general information for the Rocky Mountain west, and information specific to the oil shale areas. The evaluation and analysis of these materials have not been comprehensive from the viewpoint of a complete and adequate synthesis of the data and information, an exercise which really is needed. However, the evaluation of the material has been sufficiently complete to gain a picture of the existing terrain, its cover, and its meteorology and climate, as well as the chemical and visual quality of the atmosphere over the region. From this picture of the region, a list of information and data needs required of local and mesoscale air quality models for the Green River area has been derived.

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Related Studies, General Information and Bibliography

by

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Interagency Agreement AD89F20970
with the U.S. Department of Energy

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ABSTRACT

This report identifies meteorological and air quality data sources for the oil shale areas of Western Colorado, Eastern Utah and Southern Wyoming. The information and bibliography identified in this report are not complete, or exhaustive, but consist of the material collected during 1980-1982 as part of the Green River Ambient Model Assessment program. These materials were collected with three criteria in mind: generic information applicable to the oil shale area, general information for the Rocky Mountain west, and information specific to the oil shale areas. The evaluation and analysis of these materials have not been comprehensive from the viewpoint of a complete and adequate synthesis of the data and information, an exercise which really is needed. However, the evaluation of the material has been sufficiently complete to gain a picture of the existing terrain, its cover, and its meteorology and climate, as well as the chemical and visual quality of the atmosphere over the region. From this picture of the region, a list of information and data needs required of local and mesoscale air quality models for the Green River area has been derived.

This report is being submitted in partial fulfillment of the U.S. Environmental Protection Agency Interagency Agreement AD89F20970 with the U.S. Department of Energy. The objective of this program is to produce improved, site-specific air quality models for analyzing the environmental impacts from the anticipated development in the region of the Green River Oil Shale Formation.

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SECTION 1

INTRODUCTION

Under an Interagency Agreement between the U.S. Department of Energy and the U.S. Environmental Protection Agency, the Pacific Northwest Laboratory (PNL) operated by Battelle Memorial Institute was charged with the development and validation of air quality simulation models for the oil shale area of Colorado, Utah and Wyoming. These models are to be designed in a modular structure so that additional model components, or modules, may subsequently be incorporated without significantly affecting the overall framework code. Given these models, the EPA and the oil shale industry will be able to more accurately assess the environmental impacts of a developing industry. Accurate assessments of the air quality impacts are required if federal, state and local governments are to impose siting restrictions and emission controls that preserve environmental quality while not inflicting unnecessary economic penalties on the developers of the resource.

The models being developed under this Interagency Agreement will be capable of addressing the short- and long-term average regulations for the criteria pollutants (NAAQS), the PSD regulations for SO_2 and particulate matter in Class I and Class II areas. In addition, the models will be capable of accepting modules to address the origin, fate and impacts of pollutants producing photochemical smog, acidic soils and waters, and visibility degradation in the forms of plume blight, veiled haze and regional haze, which may be later developed.

This report is one in a series of reports that addresses the development, formulation and documentation of the models described in the Interagency Agreement. In particular, this report identifies and evaluates data and information sources that were collected during 1980-1981 as part of the Green River Ambient Model Assessment program.

The organization of the report is as follows. Section 2 gives the summary and conclusions of the study, while Section 3 lists the recommendations for further studies arising out of the current analyses. Background materials concerning the oil shale areas of Utah, Colorado and Wyoming, the specific resource areas and the companies leasing or owning the resource, air quality issues, and data requirements of air quality models are presented in Section 4. The identification and evaluation of the data and information sources collected during the first few years of the project are given in Section 5. Section 6 briefly lists some of the research needs identified during the current study for the Green River Area. Finally, three Appendices are included:

- Appendix A: Annotated Bibliography of Literature and Data Applicable to the Oil Shale Area.

The bibliography given in this appendix consists of 88 references segregated into 11 categories:

--- General Environmental Studies	15 References
--- Status of the Oil Shale Tracts	5 References
--- General Bibliographies	2 References
--- Source Data and Information	4 References
--- Terrain Data and Information	2 References
--- Climate and Meteorological Data	8 References
--- Local Flow and Diffusion Studies in Colorado and Utah	13 References
--- Visibility	7 References
--- Air Quality Related Values	7 References
--- Health and Socioeconomic Impacts	4 References
--- Flow and Diffusion Model Development and Model Performance	21 References

- Appendix B: Bibliography of Literature and Data Applicable to the Oil Shale Area.

The bibliography given in this appendix consists of 760 references segregated into 13 categories and classified according to their area of applicability (oil shale area, Rocky Mountains, generic), space scales (micro, local, meso, regional), and time scales (minutes, hours, days, seasons). The categories considered are:

--- Source Emissions	99 References
--- Terrain.	21 References
--- Meteorology.	275 References
--- Chemistry.	86 References
--- Removal.	38 References
--- Visibility	37 References

--- Effects (Air Quality Related Values)	28 References
--- Instrument Systems	43 References
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- Appendix C: Maps of Land-Surface Forms and Selected Terrain Profiles for the Green River Formation Study Area.

  This appendix contains maps of the mesoscale domain covering the oil shale regions of Wyoming, Utah and Colorado. This domain is defined as the area bounded by 106° and 112° west longitude by 38° and 44° north latitude. The maps include:

  -- Geographic maps showing towns, rivers and mountains.

  -- Land-surface form maps for determining surface roughness on a mesoscale resolution.

  -- Terrain profiles across the mesoscale domain at 1/10° latitude and longitude resolution.

In addition, terrain profiles are given across the Piceance Basin oil shale area on the township grid, with a map resolution of 3 kilometers.

SECTION 2

SUMMARY AND CONCLUSIONS

The identification and evaluation of information and data sources for the Green River Area requires a search of the open literature, company PSD permits and other environmental reports, research reports from federal and state agencies, and data from many other sources. Some of the information and data are freely available to the public, while other data fall under the proprietory policies of the oil companies in question. This report is concerned with the data and information collected by the Green River Ambient Model Assessment Program, and the evaluation is made in the spirit of guiding future research in the Green River Area. The following summary items and conclusions are a result of the current study.

- This report summarizes the current knowledge of the terrain and its cover, the meteorology and climate, and the air quality and visual characteristics for the oil shale region of Colorado, Utah and Wyoming.
- This report shows the location of the major oil shale tracts in Colorado and Utah, and lists the major companies and agencies (federal, state and local) involved in the development of this resource.
- This report discusses the air quality issues of concern to the developers, regulators, interested parties, and the public-at-large in the Green River Area. The issues range from NAAQS and PSD regulations, to state regulations, to air quality related values over Class I areas, to town growth, and even to global climate concerns (such as the airborne accumulation of CO_2).
- The components, or modules, of an air quality model are outlined and their data and information needs are discussed.
- To aid in the identification of information and data, an annotated bibliography (with 74 references) and a bibliography (with 760 references) are given in two appendices. Both bibliographies are segregated according to topics, such as terrain data, meteorological data, chemistry data, instrument systems, etc.

- The information and data identified and evaluated in the main part of the report considers a breakdown in terms of emissions, terrain, meteorological, and air quality data. In this discussion, 144 references are considered. Of course, there is overlap between the reference list in the main report and the lists in the two appendices.

- Comparing our analysis and evaluation of the above references to the requirements of air quality modeling for this area resulted in a list of data and information needs for the Green River Area.

- From the list of research needs, a list of recommendations were derived. See Section 3.

SECTION 3

RECOMMENDATIONS

The results of our identification and evaluation of information and data sources have led us to a set of recommendations for further study. These recommendations are based on the research needs described in Section 6 and the evaluations given in Section 5. They are:

1. Determine the diurnal and seasonal "areas of influence" of the four upper air stations (Denver, Grand Junction, Lander, Salt Lake City) in the vicinity of the mesoscale domain in Figure 2.
2. Thoroughly review, inventory, and synthesize the available oil shale tract data, and other pertinent data in the vicinity, in order to guide future research plans and modeling exercises.
3. Provide an ongoing upper air station between the Piceance Basin and the Flat Tops Wilderness Area of Colorado.
4. Provide more valley meteorological stations in the White and Colorado drainages so that drainage winds throughout the area can be better predicted.
5. Promote more cooperation between the various agencies and companies taking meteorological and air quality data in the Green River Area.
6. Investigate the potential of transferring data to the oil shale area from other major field programs throughout the country and the world.
7. Set up a priority system for carrying out the research listed in Section 6.
8. Promote a comprehensive field program over the oil shale area that can be used for model validation over diurnal and seasonal cycles.

SECTION 4

BACKGROUND

Before identifying and evaluating data and information sources for the Green River Formation, it is of value to briefly consider background information.

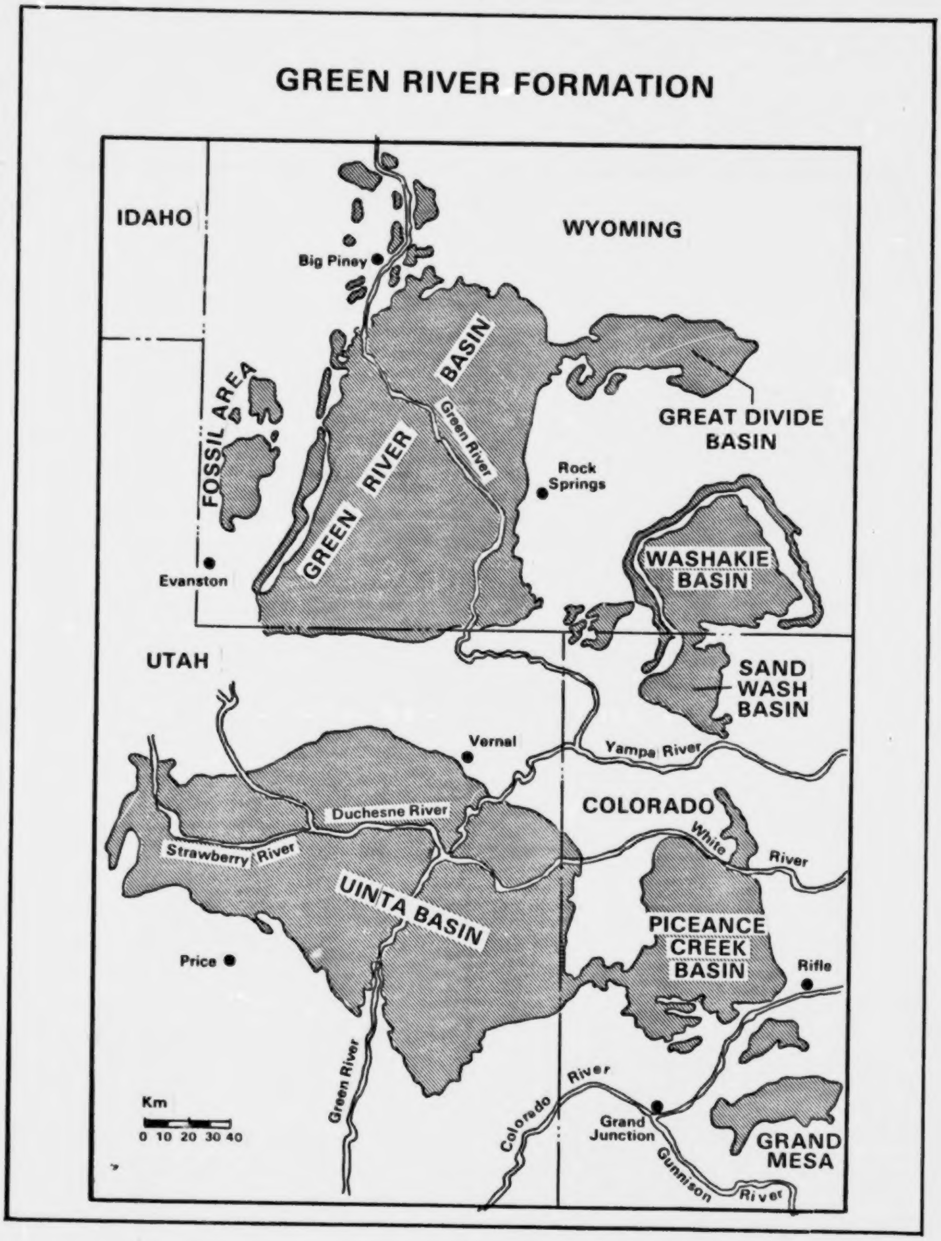
- the Region of Interest
- the Oil Shale Tracts and the Companies and Agencies Involved
- the Air Quality Issues
- the Components of an Air Quality Model and the Data Input Requirements of Such Models.

The Region of Interest subsection shows the location of the oil shale resources, describes the topography of the area, summarizes the climate and meteorology, and discusses the current state of air quality. The Oil Shale Tracts subsection gives the location of most of the current areas being developed, planning to be developed, or just under lease agreement or company ownership. In addition, the various companies and agencies involved in the region are identified and the proposed retorting processes are summarized.

The development of a mature shale oil industry in the region may produce adverse economic, social and environmental impacts in the states of Utah, Colorado and Wyoming. Many of these issues are discussed in the Air Quality Issues subsection, while the air quality models, their components and data input needs required to address these issues are outlined in the Air Quality Modeling subsection.

REGION OF INTEREST

The Green River Formation, shown in Figure 1, covers an area of about 34,000 sq. mi. (88,000 sq. km.) in Colorado, Utah and Wyoming. This geological formation can be subdivided into five basins: the Washakie and Green River Basins in southwestern Wyoming, the Uinta Basin in northeastern Utah, and the Sand Wash and Piceance Basins in northwestern Colorado. Oil shale deposits have been identified under 17,000 sq. mi. (44,000 sq. km.) of the Formation, although the concentrations of oil shale resources in the five basins vary greatly. About 84% of the total resource is located in the Piceance Basin of Colorado alone, with 10% in Utah, and 6% in Wyoming



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Evanston
UTAH
SAND WASH BASIN
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Figure 1. The Green River Oil Shale Formation of Colorado, Utah, and Wyoming.

and the Sand Wash Basin of Colorado [1]. Because the Wyoming deposits do not appear to be economically attractive, near term estimates of development only consider the oil shale region as including the Uinta and Piceance Basins. It is important to note that although Colorado has the smallest geographical areas of oil shale deposits, it also has the richest, thickest and best defined deposits. Therefore, it is likely that oil shale development will be greatest in Colorado.

All estimates for the Green River Formation indicate a vast resource which could sustain a production level of several million barrels per day far into the 21st century. To analyze the environmental impacts of such an industry (or a scaled-down version of such an industry) requires information on regional and local terrain, meteorology and climate, and background environment quality.

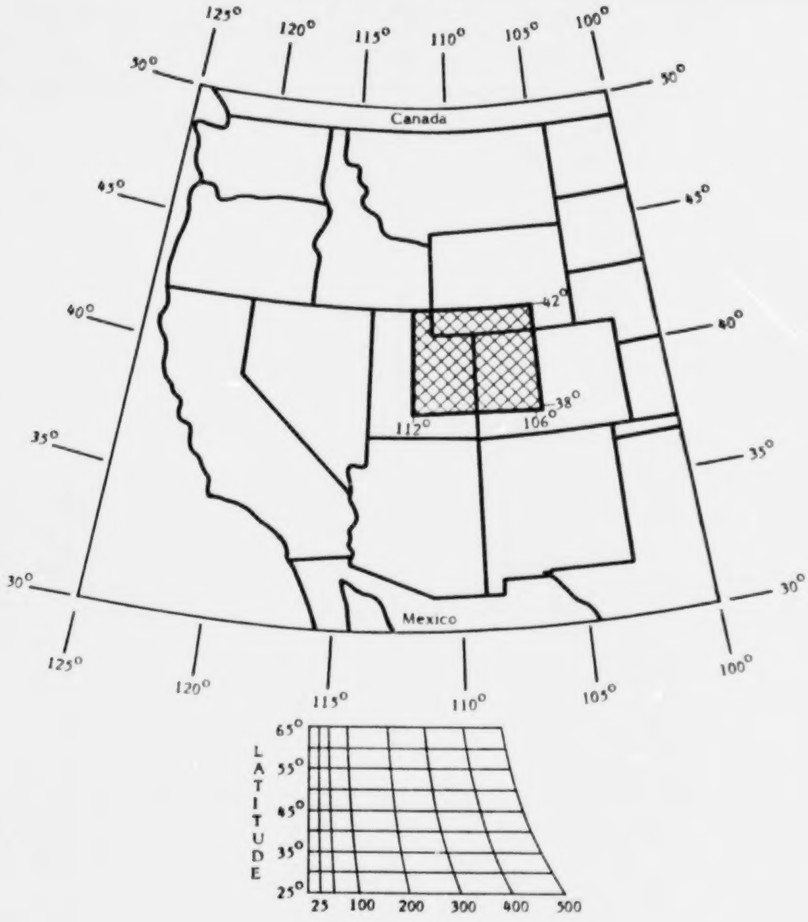
Topography

The major resource in the Utah-Colorado part of the Green River Formation can be enclosed in a mesoscale region defined by 106° to 112° west longitude by 38° to 42° north latitude, see Figure 2. The counties and county segments that lie within this region are shown in Figure 3. Table 1 gives the land area of each county (total land area of the county in all cases) and the 1980 populations, or population estimates.

This 500 km by 450 km domain is predominantly drained by the upper Colorado River System (Figures 4 and 5). The topography that surrounds or intersects the domain, and thus influences its meteorology, consists of the Wasatch Plateau and Wasatch and Wyoming Ranges to the west, the Tavaputs and Roan Plateaus to the south, the Wind River and Absaroka Ranges and Bighorn Mountains to the north, and the Park and Front Ranges to the east. In the interior of the region (Figure 5), the Green, White, Yampa and Colorado River systems and the Uinta Mountains play dominant roles in changing wind and temperature fields.

The ruggedness of the region is indicated by the 2,000 ft. contour-interval map shown in Figure 6. Emphasized on this map are the Uinta Mountains in the northwest quadrant, the Rocky Mountain Ranges along the eastern side, and the steep canyons and the Grand Valley of the Colorado River. The Flat Tops Wilderness Area is located at the intersection of 40° north latitude and 107° west longitude.

Figures 7a,b show the locations of existing and proposed Federal Mandatory Class I PSD areas nearest to the oil shale regions in Utah and Colorado. The 11,000 ft. (3,350 m) high Flat Tops Wilderness Area is the closest Class I area to the Piceance Creek Basin in Colorado; it lies about 70 km east of the Basin. The Dinosaur National Monument, which is roughly at the geometric centroid of the four major oil shale basins shown in Figure 1, is a proposed Class I area. Other Class I areas that may be affected by a regional oil shale industry are: the Arches National Park in Utah due to drainage flow down Parachute Creek and the Colorado River; the Canyonlands National Park in Utah due to drainage flows down the White, Green and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400
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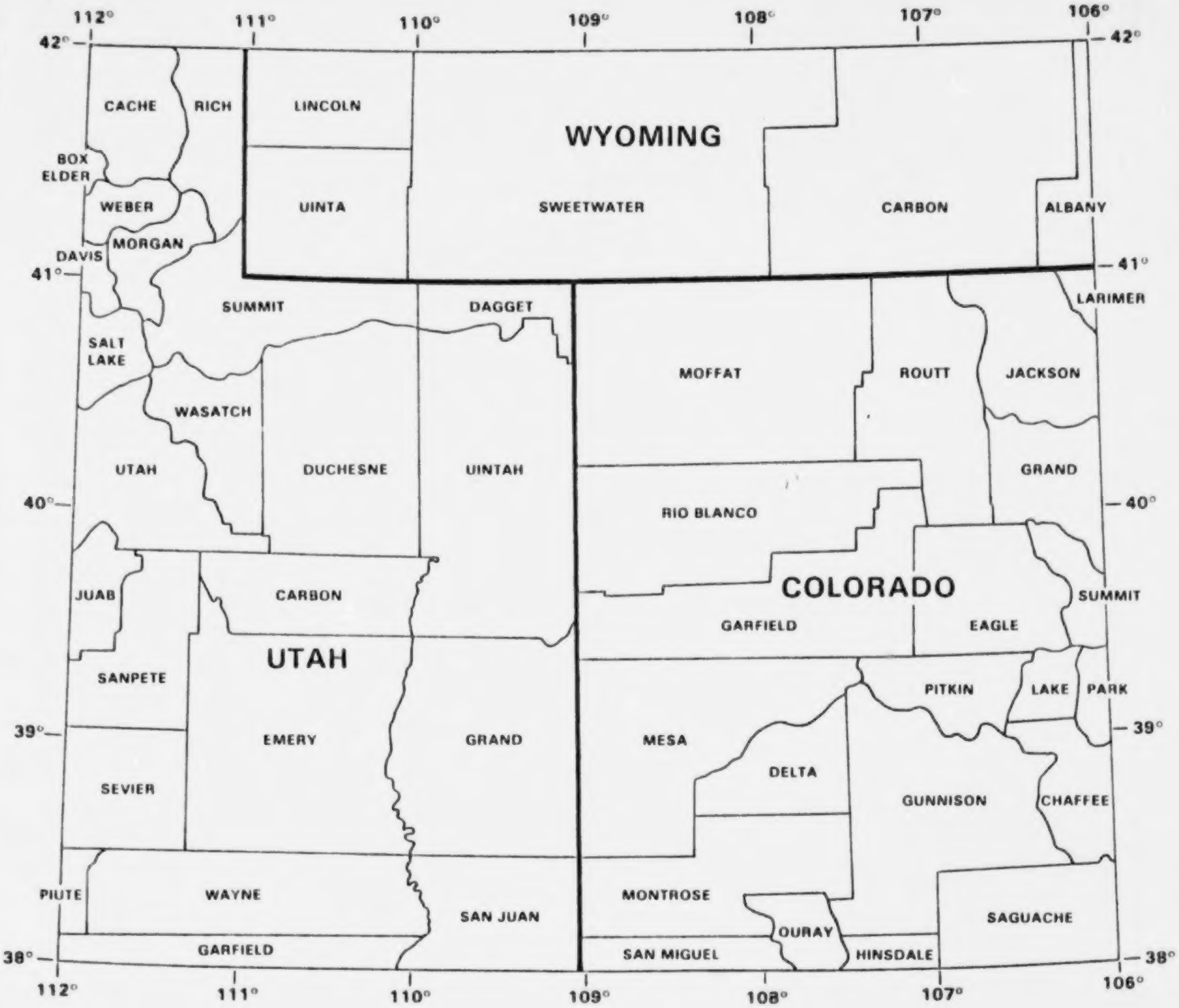
Scale of Nautical Miles at Various Latitudes

(1 Nautical Mile = 1.852 km)

Figure 2. The mesoscale domain of computation (cross-hatched area) for the Green River Formation in relationship to the Rocky Mountain west.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PIUTE
WAYNE
MONTROSE
SAN JUAN
SAGUACHE
OURAY
GARFIELD
SAN MIGUEL
HINSDALE

Figure 3. The counties of Wyoming, Utah and Colorado that wholly or partially fall within the mesoscale domain.

TABLE 1. Population and Land Area (total figures for all counties) for Counties Listed in Figure 3 [2]

State	County	County Seat or Court House	Population of County(a)	Land Area, Sq Mi
Utah	Box Elder	Brigham City	33,212	5,603
	Cache	Logan	57,220	1,174
	Carbon	Price	22,101	1,476
	Daggett	Manila	765	682
	Davis	Farmington	146,242	297
	Duchesne	Duchesne	12,537	3,255
	Emery	Castle Dale	11,455	4,439
	Garfield	Panguitch	3,660	5,158
	Grand	Moab	8,312	3,682
	Juab	Nephi	5,516	3,412
	Morgan	Morgan	4,914	603
	Piute	Junction	1,328	754
	Rich	Randolph	2,115	1,023
	Salt Lake	Salt Lake City	615,586	764
	San Juan	Monticello	12,270	7,707
	Sanpete	Manti	14,615	1,597
	Sevier	Richfield	14,742	1,929
	Summit	Coalville	10,227	1,849
	Uintah	Vernal	20,479	4,487
	Utah	Provo	217,281	2,014
	Wasatch	Heber City	8,531	1,191
	Wayne	Loa	1,918	2,486
	Weber	Ogden	143,170	581
Wyoming	Albany	Laramie	28,974	4,248
	Carbon	Rawlins	21,823	7,905
	Lincoln	Kemmerer	12,177	4,085
	Sweetwater	Green River	41,662	10,429
	Uinta	Evanston	13,021	2,086

TABLE 1. (contd)

State	County	County Seat or Court House	Population of County(a)	Land Area, Sq Mi
Colorado	Chaffee	Salida	12,100(b)	1,038
	Delta	Delta	19,600(b)	1,154
	Eagle	Eagle	12,707	1,681
	Garfield	Glenwood Springs	22,483	2,996
	Grand	Hot Sulphur Springs	7,453	1,854
	Gunnison	Gunnison	8,500(b)	3,220
	Hinsdale	Lake City	500(b)	1,054
	Jackson	Walden	1,865	1,622
	Lake	Leadville	8,000(b)	379
	Larimer	Fort Collins	149,205	2,611
	Mesa	Grand Junction	81,482	3,301
	Moffat	Craig	13,129	4,743
	Montrose	Montrose	22,200(b)	2,238
	Ouray	Ouray	1,900(b)	540
	Park	Fairplay	5,000(b)	2,162
	Pitkin	Aspen	10,222	973
	Rio Blanco	Meeker	6,294	3,263
	Routt	Steamboat Springs	13,374	2,330
	Saguache	Saguache	4,200(b)	3,144
	San Miguel	Telluride	2,900(b)	1,283
	Summit	Breckenridge	8,704	604

(a) Preliminary totals in the 1980 census, conducted on April 1, 1980 and released on October 15, 1980.

(b) Population figures listed are 1978 Census Bureau population estimates.

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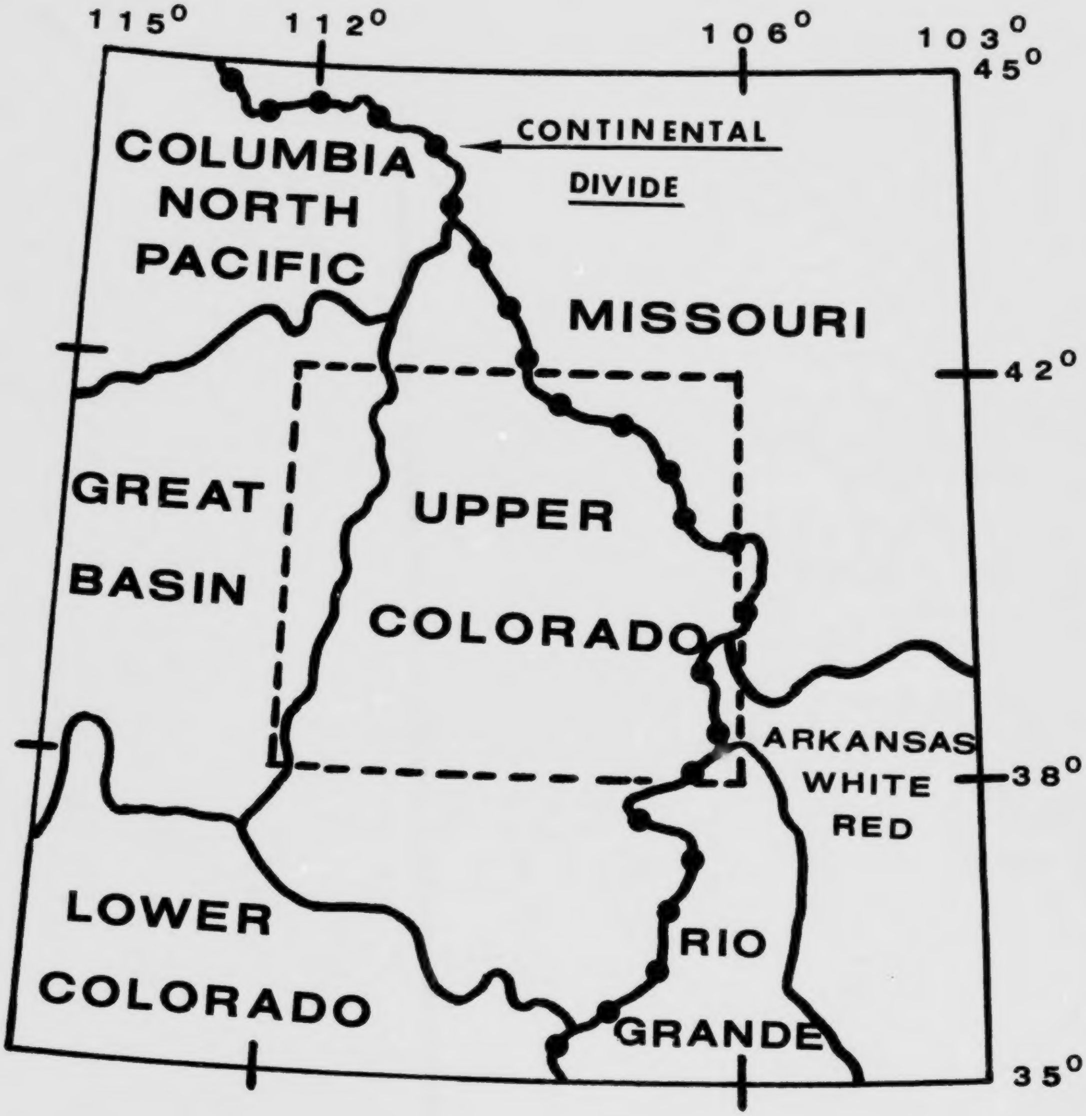
115°
112°
106°
103°
45°
42°
38°
35°
COLUMBIA NORTH PACIFIC
CONTINENTAL DIVIDE
MISSOURI
GREAT BASIN
UPPER COLORADO
ARKANSAS WHITE RED
LOWER COLORADO
RIO GRANDE

Figure 4. The major river systems draining the oil shale region.

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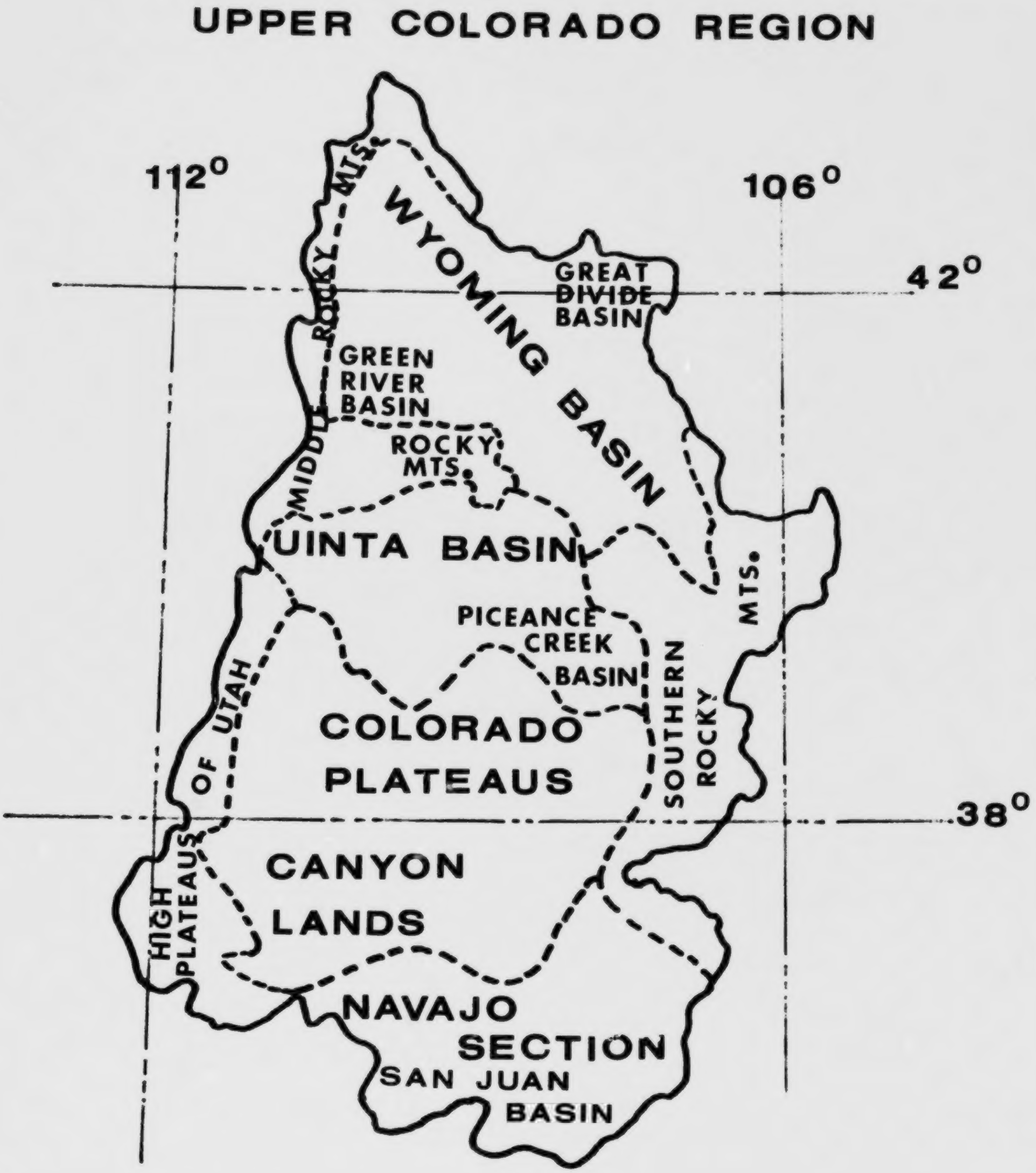
UPPER COLORADO REGION
112°
106°
42°
38°
MIDDLE ROCKY MTS.
WYOMING BASIN
GREAT DIVIDE BASIN
GREEN RIVER BASIN
ROCKY MTS.
UINTA BASIN
MTS.
PICEANCE CREEK BASIN
SOUTHERN ROCKY
HIGH PLATEAUS OF UTAH
COLORADO PLATEAUS
CANYON LANDS
NAVAJO SECTION
SAN JUAN BASIN

Figure 5. The principal physiographic subdivisions in the upper Colorado region.

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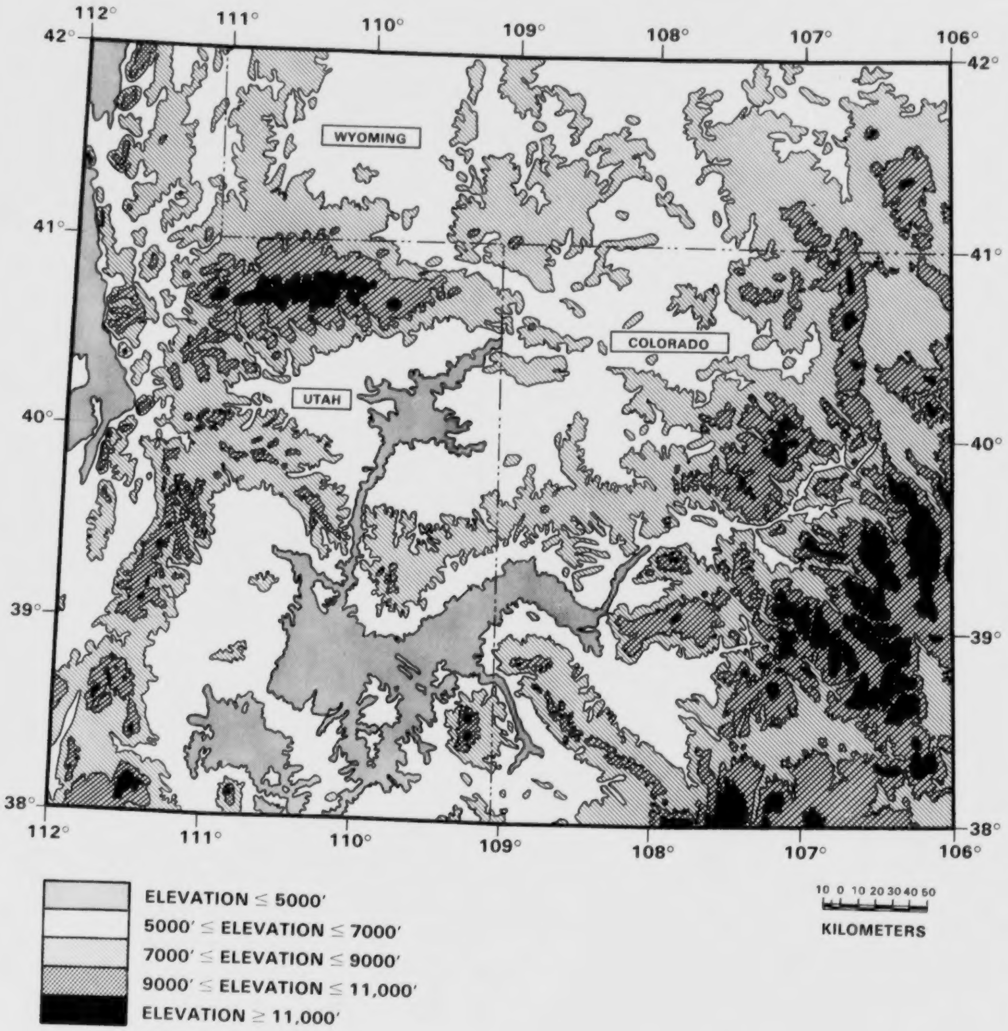
112°
111°
110°
109°
108°
107°
106°
42°
41°
40°
39°
38°
WYOMING
COLORADO
UTAH
ELEVATION ≤ 5000'
5000' ≤ ELEVATION ≤ 7000'
7000' ≤ ELEVATION ≤ 9000'
9000' ≤ ELEVATION ≤ 11,000'
ELEVATION ≥ 11,000'
10 0 10 20 30 40 50
KILOMETERS

Figure 6. The terrain contour map for the mesoscale domain, with a contour interval of 2000 feet.

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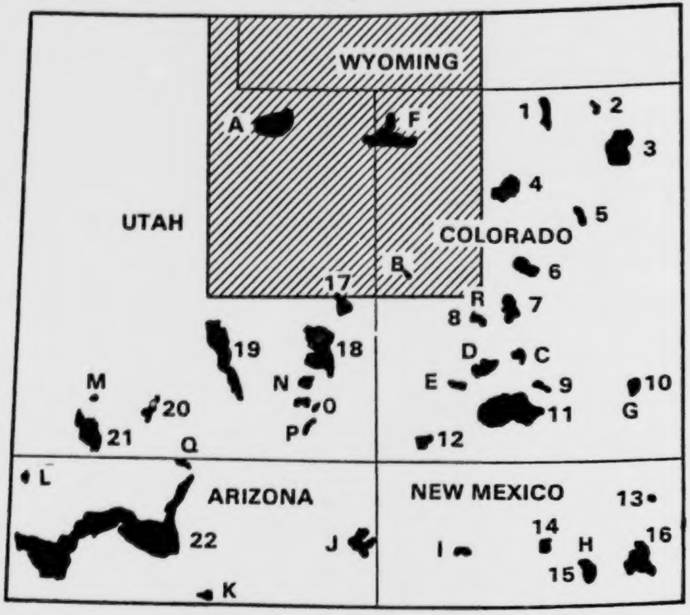
(a)



(b)

Federal Mandatory Areas

Index	Area
1	Mount Zirkel (W)
2	Rawah (W)
3	Rocky Mountain (NP)
4	Flat Tops (W)
5	Eagles Nest (W)
6	Maroon-Bells Snowmass (W)
7	West Elk (W)
8	Black Canyon of the Gunnison (W)
9	La Garita (W)
10	Great Sand Dunes (W)
11	Weminuche (W)
12	Mesa Verde (NP)
13	Wheeler Park (W)
14	San Pedro Parks (W)
15	Bandelier (W)
16	Pecos (W)
17	Arches (NP)
18	Canyonlands (NP)
19	Capital Reef (NP)
20	Bryce Canyon (NP)
21	Zion (NP)
22	Grand Canyon (NP)

Proposed Areas

Index	Area
A	High Uintas (PA)
B	Colorado (NM)
C	Powerhorn (PA)
D	Uncompahgre (PA)
E	Wilson Mountains (PA)
F	Dinosaur (NM)
G	Great Sand Dunes (NM)
H	Bandelier (NM)
I	Chaco Canyon (NM)
J	Canyon de Chelly (NM)
K	Wupatki (NM)
L	Paiute (PA)
M	Cedar Breaks (NM)
N	Dark Canyon (PA)
O	Natural Bridges (NM)
P	Grand Gulch (PA)
Q	Paria Cnayon (NM)
R	Black Canyon of the Gunnison (NM)

(W) = Wilderness Area
(NP) = National Park
(NM) = National Monument
(PA) = Primitive Area

Figure 7. Federal Mandatory Class I areas and proposed areas [3]. The shaded area in (a) represents the overlay of the map in Figure 1. The legend for the map is given in (b).

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Colorado Rivers; the Arches, Canyonlands and Capitol Reef National Parks due to higher level flows from the north to northeast; and the Mt. Zirkel Wilderness area in Colorado due to oil shale development in the Washakie and Sand Wash Basins. The rest of the area in and around the resource basins shown in Figure 1 are Class II PSD areas.

Climate and Meteorology

The climate and meteorology over the Southern Rocky Mountain region, consisting of Arizona, Colorado, New Mexico and Utah, are representative of the smaller region, the Oil Shale Region of Utah and Colorado [4]. The climate of the Southern Rocky Mountain region varies from arid and semi-arid in the desert valleys and high plains, respectively, to subarctic and polar on the high mountain summits. In general, elevation is the greatest factor in determining the climatic conditions within any specific area. However, orientation with respect to mountain barriers and the pattern of synoptic-scale weather systems dictate the seasonal and spatial distribution of climate across the region.

The Southern Rocky Mountain region is primarily a mid-latitude continental region, isolated from the Pacific Ocean and the Gulf of Mexico by great distances. The dominant airmass type that affects the region is continental (either polar or tropical). However, periodic changes in the pattern of upper-level winds allow maritime (polar or tropical) airmasses to penetrate into the region. During periods of westerly winds, when moisture-laden Pacific storms penetrate the western United States, most maritime characteristics are lost as the moisture is deposited on mountain barriers in Washington, Oregon and California. What water remains is further depleted by the intermountain barriers in Nevada and Idaho, and the result is little or no precipitation in the Southern Rocky Mountain region. Generally, only the western slopes and summits of high mountainous areas receive appreciable precipitation during Pacific airmass intrusions. In areas east of the Rocky Mountains, the contribution of water by Pacific airmasses is small. The effects of these modified Pacific maritime airmasses are limited to cloudy conditions, a general increase in surface winds, and moderating temperatures.

During periods of strong northwesterly and northerly upper-level winds, continental airmasses that originate in northern Canada and on the Canadian prairies penetrate the region, bringing colder temperatures and dry conditions. Although these continental airmasses can affect areas as far south as Arizona and as far west as Utah, their effects are usually restricted to areas east of the Rocky Mountains. Because these cold air masses are typically shallow, westerly penetration over the Rocky Mountains is limited to only very strong intrusions.

During periods of southerly and southeasterly flow, moist maritime tropical air frequently moves up from the Gulf of Mexico and can penetrate all but the extreme northern portions of the region. This type of airmass provides most of the precipitation that falls in the lowland areas of the region. When southerly flow brings continental tropical airmasses from the

Sonoran Desert and Mexican interior, very low humidities and warm conditions prevail over the region.

During the frequent periods of light upper-air winds, the air over the region takes on its own continental airmass characteristics. These basic characteristics are clear skies and dry conditions, locally-controlled wind flow (e.g., mountain-valley circulations), a large diurnal temperature range, nighttime formation of surface temperature inversions, and good vertical mixing of air during the day.

Coldest winters in the region occur on the Great Plains and in the intermountain areas of Colorado and eastern Utah. Intrusions of polar or arctic air into these areas brings bitter cold temperatures and very dry air. Farther south and west, the winters are comparatively warmer, partly because of the protection provided by the Rocky Mountains, and partly because of the greater solar insolation in more southerly locations. For most of the winter, the Great Basin and Colorado Plateau areas are occupied by a semi-permanent high pressure system, with its associated clear skies and light winds. During these periods, general air stagnation results, and local down-slope drainage flow causes cold stable air to collect in most lowlands west of the Continental Divide. Because these conditions can persist for weeks at a time, this buildup of cold stable air can result in western valleys having temperatures well below zero, while the higher surrounding terrain remains in the warmer Pacific air. Occasionally, strong mid-latitude cyclones from the Pacific move through the region, bringing significant amounts of snow to the mountains and strong winds to the entire region. These winds tend to scour out the stable air near the surface. However, unless the movement of storms through the region continues, stable surface conditions redevelop in a few days.

Summers are cool and refreshing at high elevations in the region. Average daytime temperatures in the Rocky Mountains and in other mountainous areas of Utah, Arizona, and New Mexico, are generally near 20°C (68°F). Above 2,400 m (8,000 ft.), nights are quite cool throughout the summer, while during the day bright sunshine makes the days comfortably warm. In the lowland areas of the region, summer daytime temperatures are quite warm. In the desert valleys and on the southern plains, afternoon daytime temperatures frequently exceed 38°C (100°F). Because of the very low relative humidity accompanying these high temperatures, hot days cause less discomfort here than they do in more humid areas. During the summer, frequent afternoon thunderstorms form over the region, bringing showers and cooling to scattered areas. On the eastern plains of Colorado and New Mexico, these thunderstorms occasionally reach severe levels, spawning tornadoes, large hail, and heavy rains.

Annual precipitation varies from over 127 cm (50 in.) on Wolf Creek Pass in the San Juan Mountains of Colorado, to less than 8 cm (3 in.) at certain points in the oil shale region. In general, high mountain summits and ridge crests throughout most of the region receive most of their precipitation during the winter in the form of snow. Moist upper-level air that accompanies eastward-moving mid-latitude storm systems impinges upon the mountain slopes and is orographically lifted. This results in heavy snows on the western slopes and summits. The snow pack runoff, which develops in the spring, supplies virtually all of the water for the lowland areas of the region.

Air Quality

The current state of air quality over the Green River Formation is generally good, as indicated by the annual average visibility map given in Figure 8 [5]. However, high background concentrations of particulate matter, nonmethane hydrocarbons and oxidants occasionally occur. These concentrations may be due to natural and anthropogenic particulate releases, emissions from natural vegetation, long-range transport of anthropogenic pollutants and stratospheric intrusion of ozone. The current data bases, monitoring stations and air quality models are inadequate to determine the real reasons for these high values.

Summary

The oil shale development sites are, or will be, located in three topographically distinct areas: the Green River Basin, the Uinta Basin and the Piceance Basin, shown in Figure 1. Topographically, the Piceance Basin in Colorado has the roughest terrain of the three. The Green River Basin has the least complex terrain. In respect to climate and meteorology, the Piceance Basin probably has a higher incidence of slope-valley (local) winds because of numerous canyons and valleys. The Piceance and Uinta Basins have a high incidence of temperature inversions, probably relatively higher than the Green River Basin. High winds are generally more frequent in the Green River Basin because of the open terrain and the preferential movement of storm tracks; thus, temperature inversions and slope-valley wind systems are relatively less frequent there than in the other basins. In addition, the Uinta Basin probably has a higher frequency of strong winds than the Piceance Basin.

At the present time, the air quality in all three basins is generally excellent because of the lack of anthropogenic activity. Some natural causes, such as dust storms or vegetation emissions, result in temporary degradation in the air quality. Long-range transport of anthropogenic pollutants could become more of a problem in the future as the Rocky Mountain area becomes more industrialized and more coal-fired power plants are brough on line.

THE OIL SHALE TRACTS

Oil shale is a rock in which the mineral portion is associated with high molecular weight organic material in a complex manner. The mineral portion is primarily a marlstone or mixture of calcium and magnesium carbonates (dolomite) with smaller portions of quartz and silicates. Small amounts of aluminum materials also occur as pockets in some oil shale deposits. The organic portion is principally a material called kerogen, which is of such high molecular weight that it is not extractable by

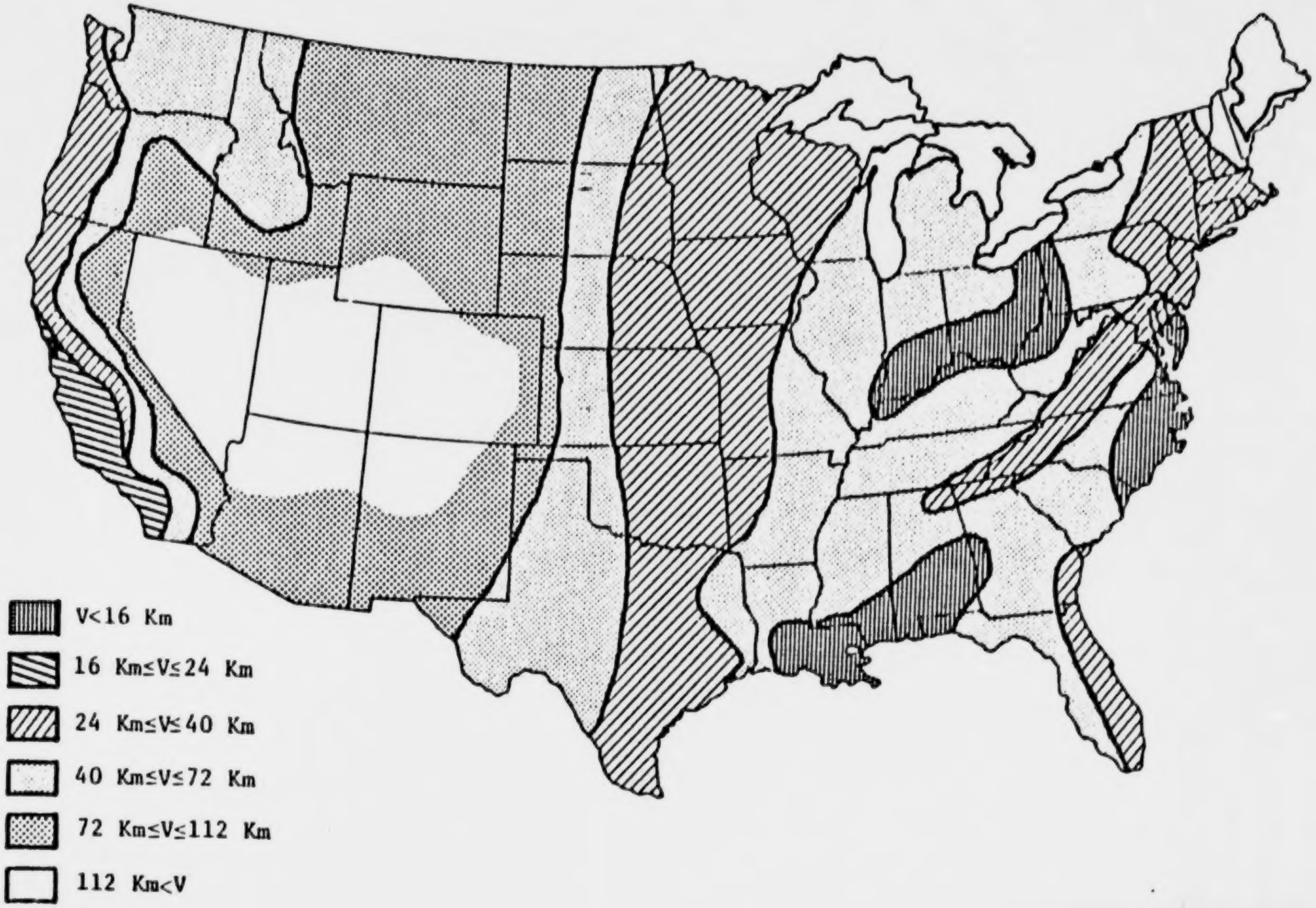
V<16 Km
16 Km≤V≤24 Km
24 Km≤V≤40 Km
40 Km≤V≤72 Km
72 Km≤V≤112 Km
112 Km<V

Figure 8. Shaded isopleths of yearly average visibilities, given in terms of visual range V in kilometers [5].

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ordinary aromatic solvents. A second constituent is bitumen, which is extractable by benzene and other solvents.

In order to obtain oil from this material, it is necessary to decompose the kerogen in some manner and convert it into compounds that can be separated from the mineral matter either by distillation or solvent extraction. Oil retorting processes currently under investigation use heat, usually derived from combustion of a small part of the material used in the process, to achieve this goal.

Figure 9 is a schematic of shale fuel cycles from exploration, to product extraction, to product upgrading, and finally to the end uses of the oil and gas products. At each stage of these cycles, the unit operations will emit airborne pollutants in one or more of three modes: controlled emissions, process upsets, and fugitive emissions. The magnitude, location and time history of these emissions will be dependent on the size of the facilities, the control technologies employed, and the specific oil shale retorting, upgrading and waste management technologies used. This subsection of the report gives the location of the oil shale tracts in Utah and Colorado, lists the key companies involved with developing shale oil, lists the key government agencies and other groups involved in the oil shale industry, and briefly describes the oil shale technologies being considered. The emissions from the proposed facilities will be discussed in Section 5.

Location of the Oil Shale Tracts

Recently, there have been several surveys showing the locations, describing the technologies, and outlining the development timetables and production projections of oil shale projects in the tri-corner area of Colorado, Utah and Wyoming [7 to 11]. The projections given in these surveys vary, depending on the judgments of the authors, the information sources used by the authors, and the timeliness of the data used in the surveys. Possibly, the best surveys are given in [8,9,11].

In [8], the USGS Oil Shale Office in Grand Junction describes 15 active projects in the Utah-Colorado area. The information listed includes the developer, the resource potential of the site, mining and retorting methods being used or proposed, employment projections, and status as of 1981. Because of rapid and frequent changes in engineering design of each project, the Oil Shale Office does not guarantee that the information contained in the summaries is totally accurate. In fact, the Oil Shale Office requests that anyone with more up-to-date data contact them so that the next edition is more accurate.

The draft report of the Oil Shale Task Force of the American Petroleum Institute (API), see [9], discusses 17 individual projects in the states of Utah and Colorado. Reference [11] considers 18 sites in an EPA study concerned with the PSD policy implications on a developing shale oil industry. In this last study, the investigators considered three emission source areas (Figure 10a) with several sites, or oil shale tracts, in each source area:

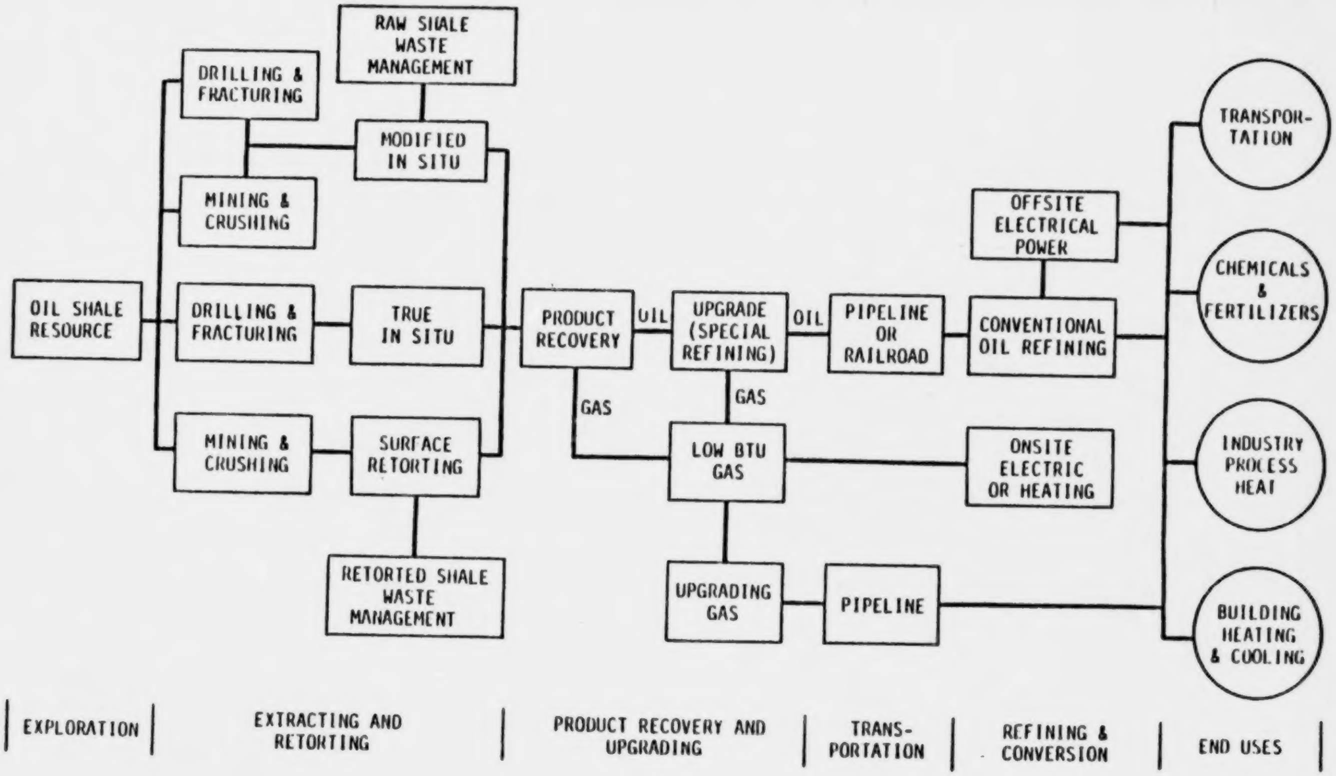
OIL SHALE RESOURCE
DRILLING & FRACTURING
MINING & CRUSHING
DRILLING & FRACTURING
MINING & CRUSHING
RAW SHALE WASTE MANAGEMENT
MODIFIED IN SITU
TRUE IN SITU
SURFACE RETORTING
RETORTED SHALE WASTE MANAGEMENT
PRODUCT RECOVERY
OIL
GAS
UPGRADE (SPECIAL REFINING)
OIL
GAS
LOW BTU GAS
UPGRADING GAS
PIPELINE OR RAILROAD
PIPELINE
OFFSITE ELECTRICAL POWER
CONVENTIONAL OIL REFINING
ONSITE ELECTRIC OR HEATING
TRANSPORTATION
CHEMICALS & FERTILIZERS
INDUSTRY PROCESS HEAT
BUILDING HEATING & COOLING
EXPLORATION
EXTRACTING AND RETORTING
PRODUCT RECOVERY AND UPGRADING
TRANS-PORTATION
REFINING & CONVERSION
END USES

Figure 9. Shale fuel cycles [6].

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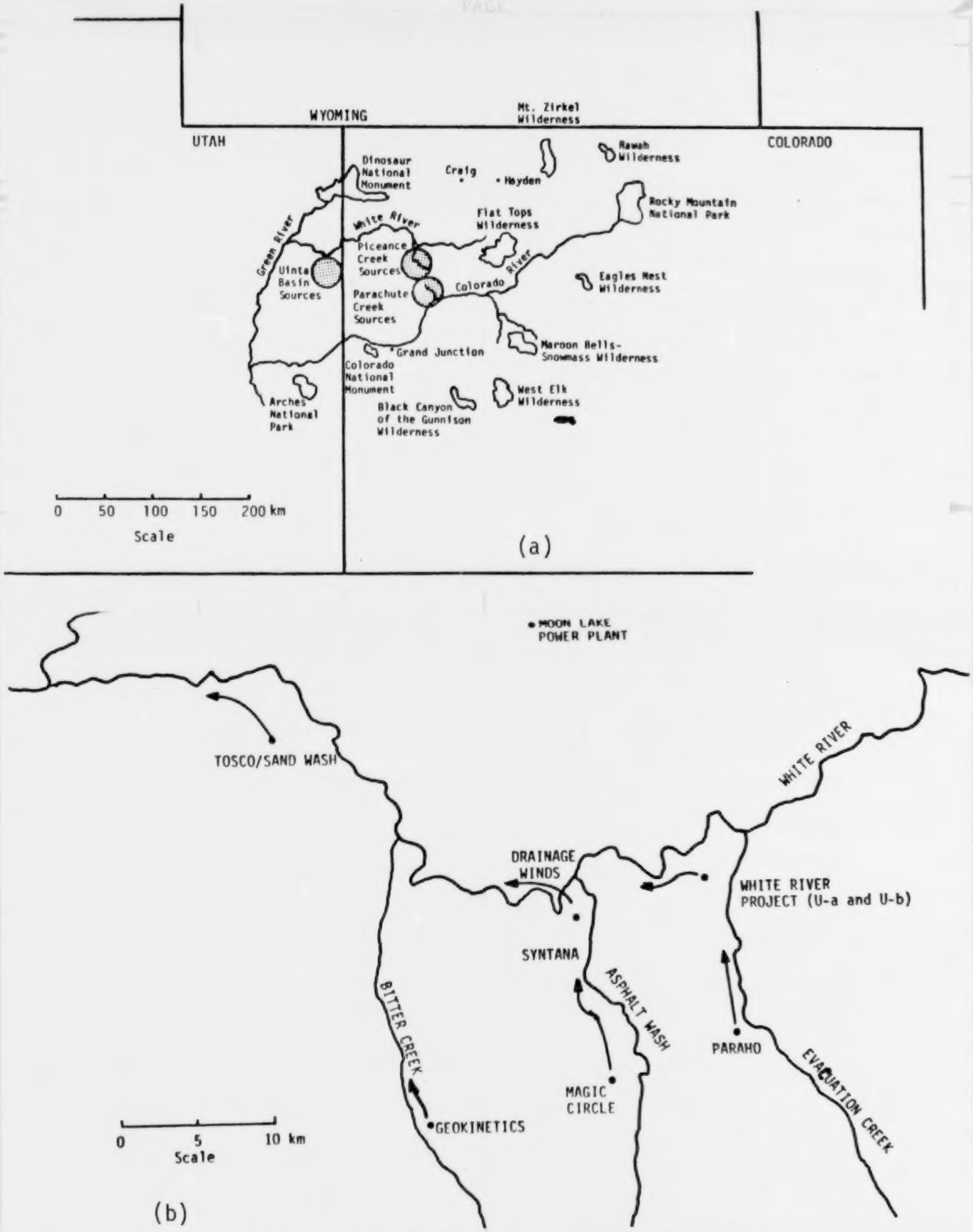

WYOMING
Mt. Zirkel Wilderness
UTAH
COLORADO
Rawah Wilderness
Dinosaur National Monument
Craig
Hayden
Rocky Mountain National Park
White River
Flat Tops Wilderness
Green River
Piceance Creek Sources
Uinta Basin Sources
Colorado River
Eagles Nest Wilderness
Parachute Creek Sources
Grand Junction
Maroon Bells-Snowmass Wilderness
Colorado National Monument
West Elk Wilderness
Arches National Park
Black Canyon of the Gunnison Wilderness
0 50 100 150 200 km
Scale
(a)
MOON LAKE POWER PLANT
TOSCO/SAND WASH
WHITE RIVER
DRAINAGE WINDS
WHITE RIVER PROJECT (U-a and U-b)
SYNTANA
ASPHALT WASH
BITTER CREEK
PARAHO
EVACUATION CREEK
MAGIC CIRCLE
GEOKINETICS
0 5 10 km
Scale
(b)

Figure 10. (a) Locations of emission source areas relative to existing mandatory and potential Class I areas in our region of study. (b) Assumed locations of sources in the White River (Uinta) Basin in Utah (the arrows indicate the direction of nocturnal drainage flows), [11].

- Uinta Basin Sources (Figure 10b): 6 sites.
- Piceance Creek Sources (Figure 11a): 5 sites.
- Parachute Creek Sources (Figure 11b): 7 sites.

Companies, Agencies, and Other Groups

The particular companies and government agencies involved in the development of oil shale resources vary as the economy and government philosophies and policies vary. The price of oil influences the need, or lack of need, for synthetic fuels, while changing government philosophies and policies encourage, or discourage, their development. Hence, the participants in the slowly developing oil shale industry are constantly in a state of flux. Tables 2 and 3 summarize a recent (as of January 1982) listing of the major actors in this evolving system. The key companies are listed in Table 2, while Table 3 gives the key government agencies and other groups.

Retorting Technologies

Shale oil can be produced from oil shale by three general retorting processes [6,10,14]: surface or above ground, modified in situ, and true in situ. In each case, the oil shale must be heated (retorted) to 400°C or higher to bring about pyrolysis of the kerogen and production of shale oil and gas. The process used depends on the depth, assay, and geographic location of the shale formation or deposit, and on technological, economic, and environmental factors.

Surface retorting processes require mining of oil shale, either by underground or surface methods. The mined oil shale must be crushed and sized before retorting. The spent oil shale rock must be disposed of in environmentally acceptable ways.

Two methods of surface retorting are the direct- and the indirect-heated methods. The heat required to break down the kerogen for the direct-heated process is supplied by a combustion zone within the retort, sustained by gases released from the heated oil shale. In the case of indirect-heated processes, gases are circulated to an external heat exchanger, where heat is transferred to the retort by recirculating solids or the gases through the retort. The products and residuals from these two methods for producing oil and gas differ somewhat in their chemical properties.

True in situ processes involve underground retorting with no mining or disposal of retorted oil shale. The oil shale formation is first fractured (using a hydraulic explosive fracturing technique) to provide the necessary surface area and permeability for combustion and thermal conduction to occur. The oil shale is then ignited via a central injection well, and combustion is sustained by pumping compressed air into the injection well.

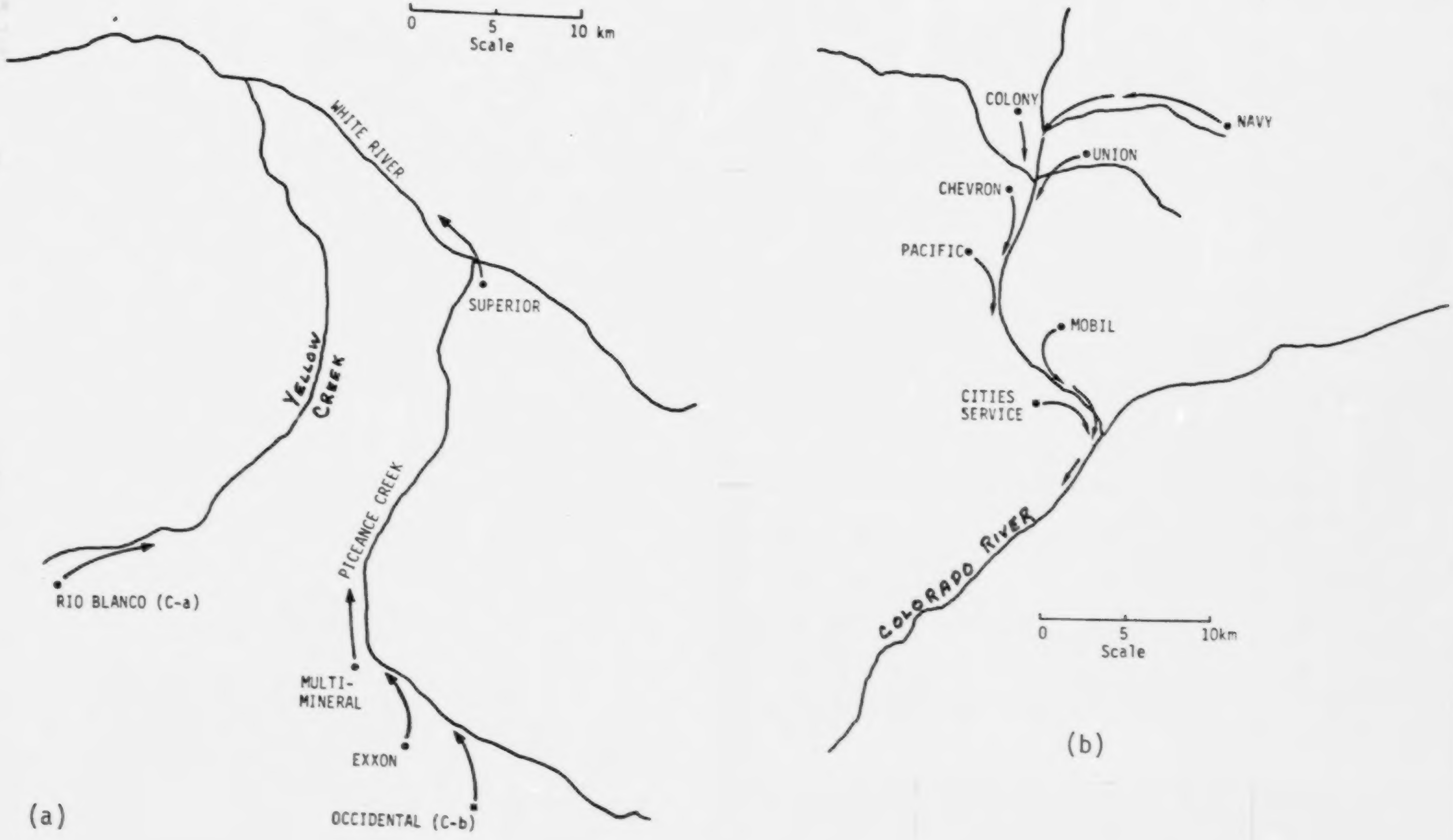

0
5
10 km
Scale
WHITE RIVER
SUPERIOR
YELLOW CREEK
PICEANCE CREEK
RIO BLANCO (C-a)
MULTI-MINERAL
EXXON
OCCIDENTAL (C-b)
(a)
COLONY
NAVY
UNION
CHEVRON
PACIFIC
MOBIL
CITIES SERVICE
COLORADO RIVER
0
5
10km
Scale
(b)

Figure 11. (a) Schematic of drainage flows in the Yellow and Piceance Creek Basins and assumed locations of oil shale facilities. (b) Schematic for the facilities in the Parachute Creek Basin, [11].

TABLE 2. Key Companies Involved with Developing Shale Oil [12]

Company	Parent Company	Oil Shale Activity	Location of Activity	Location of Local Office	Comments
ARCO Atlantic Richfield	---	Owner of extensive oil shale lands	Western Colorado	(Public Info. Office) Denver, CO	Formerly part of Colony and C-b Tract
Cathedral Bluffs Shale Oil Co.	Occidental Oil Shale, Inc. and Tenneco Shale Oil Co.	Development of tract C-b	Piceance Creek Basin	(Public Affairs, Tech. Manager) Grand Junction, CO	Tract operated by Occidental Oil Shale, Inc.
Chevron Shale Oil Co.	Standard Oil of California	Largest landowner of private oil shale lands in Colorado	(Clear Creek Shale Oil Project) Western Colorado	(Public Affairs) Denver, CO	Investigating the feasibility of a commercial project
Colony Shale Oil Project	Exxon Corp. and The Oil Shale Corp. (Part of Tosco)	Oil Shale development on private land (Colony or Dow)	Parachute Creek Basin	(Public Affairs) Aurora, CO (Exxon Co.) Denver, CO	On 5/2/82 it was announced that work would cease and Tosco had sold its 40% to Exxon [13]
Colorado Mining Association	Trade Association for the Mining Industry	Companies and individuals active in various stages of mining	Colorado	(Secy and manager) Denver, CO	---
Equity Oil Co.	---	Oil Shale research and development	Piceance Creek Basin	(Secy) Salt Lake City, UT	---
Geokinetics Inc.	---	Testing its horizontal in-situ retorting process	70 mi. South of Vernal, UT	(President) Salt Lake City, UT	Has property in the Bitter Creek Basin of Utah
Getty Oil Co.	---	Landowner and conducting shale lab research	Piceance Creek Basin	(Environ. Coor.) Denver, CO	---
Mobil Oil Corp.	---	Landowner	Parachute Creek Basin	Mining and Coal Div., Denver, CO	---
Multi-Mineral Corp.	---	Testing methods of mining nahcolite (sodium lease)	Piceance Creek Basin	(President) Grand Junction, CO	Leased lands 8 miles east of Colorado tract C-a
Occidental Oil Shale, Inc.	Occidental Petroleum Corp.	Private oil shale venture MIS retorting process	Logan Wash operations near De Beque CO	(Public Affairs) Grand Junction, CO	Also part of tract C-b--see Cathedral Bluffs
Paraho Oil Shale Demonstration	Paraho Development Corp.	Private funded project to develop Paraho process	Naval oil shale reserves, near Rifle, CO	(Chief Ex. Officer) Grand Junction, CO	Demonstration was at the Anvil Points Oil Shale Mine and Retorting Facility. Also, Involved with designing a DOD 10,000 BPD module retort
Paraho-Ute Shale Oil Facility	Paraho Development Corp.	Feasibility study for a 30,000 BPD commercial facility	Evacuation Creek near Vernal, Utah	(Chief Ex. Officer) Grand Junction, CO	---

TABLE 2. (contd)

Company	Parent Company	Oil Shale Activity	Location of Activity	Location of Local Office	Comments
Phillips Petroleum Co.	---	One of the developers of U-a and U-b in Utah; leases land in Colorado near C-a	Evacuation Creek, Utah and Yellow Creek, Colorado	(Manager) Englewood, CO	Called the Mahogany Shale Project
Rio Blanco Oil Shale Co.	Gulf Oil Co. and Standard Oil of Indiana	Development of federal tract C-a	Yellow Creek Basin	(Corp.) Aurora, CO	---
Rocky Mountain Oil and Gas Association (RMOGA)	Trade Association	Has oil shale committee	Colorado and Utah	(committee) Denver, CO	---
Skyline Oil Co.	Texas Eastern Corp.	Major oil shale landowner in Utah	Near U-a and U-b in Utah	(Senior V. Pres) Salt Lake City, Utah	---
Sohio Shale Oil Co.	Standard Oil of Ohio	One of the developers of U-a and U-b (White River Shale Oil Corp.)	Evacuation Creek Basin	(Manager) Salt Lake City Utah	Has other oil shale lands in Utah and Colorado
(Sunedco) Sunoco Energy Development Co.	Sun Oil Co.	One of the developers of U-a and U-b (White River Shale Oil Corp.)	Evacuation Creek Basin	(President) Dallas, Texas	---
Syntana-Utah Shale Oil Project	Magic Circle Energy Corp. and Synthetic Oil Corp. of Oklahoma City	Plan to have a 16,500 BPD plant	East of Bonanza, Utah	(Project Director) Houston, TX	Project operated by Quintana Minerals Corp.
Texaco, Inc.	---	Conducting in-situ retorting field test	Uintah County, Utah	(Public Affairs) Denver, CO	---
The Superior Oil Co.	---	Testing retorting and mineral recovery processes	Private shale lands near Meeker, Co	(Manager) Englewood, CO	---
Tosco Corp.	---	Lessee of shale lands in Utah	Tosco, Sand Wash, Utah	(Public Affairs) Boulder, CO	Was part of colony shale oil project [13]
Union Oil Co. of California	---	Constructing a 10,000 BPD facility	Parachute Creek Basin	(Manager) Grand Junction, CO	---
Utah Mining Association	Trade association of the mineral industry	Companies and individuals active in various stages of the industry	Utah	(Ex. V. Pres) Salt Lake City, Utah	---
White River Shale Oil Corp.	Phillips Petroleum Co. and Sohio Shale Oil Co. and Sunoco Energy Development Co.	Operator of federal tracts U-a and U-b	Uintah County, Utah	(President) Salt Lake City, Utah	---

TABLE 2. (contd)

Company	Parent Company	Oil Shale Activity	Location of Activity	Location of Local Office	Comments
Wyoming Mining Association	Trade association of the mineral industry	Companies and individuals active in various stages of the industry	Wyoming	(Ex. V. Pres.) Cheyenne, WY	---
W-a and W-b	---	No activity	Washakie Basin, WY	---	Federal lease tracts in Wyoming---no activity

TABLE 3. Key Government Agencies and Other Groups Involved With Developing Shale Oil [12]

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
Bureau of Land Management	U.S. Department of Interior	Manages the oil shale resource lands of the federal government	Denver, CO
Bureau of Mines	U.S. Department of Interior	Performs research, provides information and enforces laws concerning the extraction, processing, use and disposal of oil shale	Denver, CO
Bureau of Reclamation	U.S. Department of Interior	Oversees the development of water and related land resources	Salt Lake City, UT
Club 20	Western Colorado association of communities and industry	Dedicated to economic stability and orderly economic development of the oil shale resource	Grand Junction, CO
Colorado Department of Health	Colorado State Agency	Health and environmental health regulations related to oil shale, such as air quality, water quality, and solid waste	Denver, CO
Colorado Energy Research Institute	State agency, affiliated with Colorado School of Mines	Coordinates research on Colorado's energy studies	Lakewood, CO
Colorado Geological Survey	Colorado Department of Natural Resources	Involved in oil shale planning studies and publishes reports on oil shale	Denver, CO

TABLE 3. (contd)

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
Colorado School of Mines	State supported institution	Sponsors annual oil shale symposium and other seminars on oil shale. Research and courses on oil shale	Golden, CO
Colorado State University	State university	Involved in oil shale research, particularly in revegetation and air quality	Fort Collins, CO
Colorado Water Conservation Board	Colorado Department of Natural Resources	Studies problems concerning water supply, water use, water rights, and water quality	Denver, CO
(COG) Colorado West Area Council of Governments	Local governments on Colorado's western slope	Addresses regional concerns and channels government funds to reduce duplicity among its members	Rifle, CO
Denver Research Institute	University of Denver	PRIVATE UNIVERSITY Scientists and engineers engaged in contract research for government and industry	Denver, CO
Laramie Energy Technology Center and Laramie Energy Research Center	U.S. Department of Energy	Process research in oil shale, especially for in-situ processes	Laramie, WY
U.S. Department of Energy	---	Responsible for major federal energy programs, policies, and research and development	Germantown, MD

TABLE 3. (contd)

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
U.S. Department of Interior	---	Responsible for the administration of federal lands: management, conservation, development of resources	Denver, CO
U.S. EPA	---	Responsible for researching, monitoring and regulating environmental quantities	Region VIII Denver, CO
U.S. Geological Survey	U.S. Department of Interior	Determines mineral resources and geological structure: exploration, mapping, research	Denver, CO
Lawrence Livermore National Laboratory	University of California manages laboratory for U.S. Department of Energy	Oil shale research: air quality, chemistry of retorting, general planning	Livermore, CA
Ed. Herschler	State of Wyoming	Governor	Cheyenne, WY
Richard Lamm	State of Colorado	Governor	Denver, CO
Scott Matheson	State of Utah	Governor	Salt Lake City, UT
Mountain Plains Federal Regional Council	U.S. Government	Coordinates the participation of federal agencies interested in shale development, including assistance to oil shale communities	Denver, CO

TABLE 3. (contd)

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
Northwest Colorado Consortium for Training and Education	Consortium of Colorado Mountain College, Mesa College, and Colorado Northwestern Community College	To meet the needs of the oil shale industry for locally trained skilled workers	Mesa College, Grand Junction, CO
Oil Shale Environmental Advisory Panel	Members are from federal, state and local governments, and from industry	An advisory body that evaluates development plans and makes recommendations to U.S. DOI	Denver, CO
Oil Shale Office	USGS of U.S. Department of Interior	Supervision of operations under U.S. DOI's oil shale leasing and development program	Grand Junction, CO
Socio-Economic Impact Coordinator (Colorado)	Colorado Department of Local Affairs	Coordination of state oil shale planning efforts	Denver, CO
U.S. Soil Conservation Service	U.S. Department of Agriculture	Research, analysis and assistance for oil shale reclamation projects	Denver, CO
U.S. Synthetic Fuel Corp.	Quasi-U.S. government organization	Federal financial assistance for synfuel development	Washington, D.C.

TABLE 3. (contd)

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
Pacific Northwest Laboratory	Battelle Memorial Institute manages the laboratory for U.S. Department of Energy	Conducts research in air quality, source emissions, and water quality	Richland, WA
Sandia National Laboratories	Owned by Western Electric Corp. Funding from U.S. DOE	Works with private industry to research different processing techniques for oil shale extraction	Albuquerque, NM
Uintah Basin Association of Governments	Daggett and Duchesne Counties of Utah	Works for intergovernment cooperation and does blanket planning	Roosevelt, UT
Uintah Basin Energy Planning Council	Uintah, Duchesne and Daggett Counties of Utah	Council acts as state's advisor on basin energy impacts and does oil shale planning for local governments	Vernal, UT
University of Colorado	Colorado State Institution	Research on oil shale development and impacts	Boulder, CO
University of Utah	Utah State Institution	Energy research center and mining research	Salt Lake City, UT
Upper Colorado Environmental Plant Center	Established in cooperation with U.S. SCS and two local Colorado oil conservation districts	Test seeds and plants for oil shale reclamation programs	Meeker, CO

TABLE 3. (contd)

Key Government Agency	Parent Agency or Organization	Oil Shale Activity or Responsibility	Location of Local Office
Utah Department of Community and Economic Development	State of Utah	Coordinates socio-economic issues related to synfuels development	Salt Lake City, UT
Utah Department of Natural Resources and Energy	State of Utah	Regulates and leases state lands	Salt Lake City, UT
Utah State University	State of Utah	Research in water problems involved in energy development	Logan, UT
Western Energy Land Use Team	U.S. Fish and Wildlife Services	Determines research needs relating to energy development and its effects on wildlife	Fort Collins, CO
Western Governors Policy Office	Independent organization of governors of 11 states	To meet challenges posed by expanded state responsibilities in management and protection of human and natural resources	Denver, CO
Western Interstate Energy Board	State government agency representing 16 Western States	Represents the states on energy, natural resources, and environmental law issues	Denver, CO
Wyoming Geological Survey	State of Wyoming	Involved in surveying and studying oil shale lands	Laramie, WY

Produced gases and liquids are forced or pumped horizontally through the fracture system to production wells which surround the injection well.

The modified in situ process involves mining about 10 to 30 percent of the shale to increase the void volume for in situ retorting. The remaining oil shale (directly above the mined zone) is fractured and retorted in place. Retorting in the modified in situ process can be accomplished by forcing the combustion zone to move horizontally for thin shale deposits or vertically (top to bottom) for thick deposits. The mined shale fraction can be processed in a surface retort.

Although there are more than 3,000 patents related to oil shale recovery and processing, only a few are considered applicable to Western U.S. shales. Some of the best-known technologies are listed in Table 4 [14].

AIR QUALITY ISSUES

An expanding industry, such as the Utah-Colorado oil shale activity, releases waste products to the atmosphere from mining and production operations, secondary activities (i.e., towns, roads, airports, power plants), and construction activities. These airborne contaminants may lead to violations of state and federal regulations, degrade local and regional visibility, produce acidic soils and waters, subject workers and local residents to hazardous and toxic substances, and modify local, regional, and global weather and climate.

The concentrations of contaminants that would produce such effects are dependent on many factors:

- the location, nature, control, and magnitude of airborne emissions
- the meteorological conditions to which the emissions are subjected as they are transported, diffused, physically and chemically transformed, and removed from the air.

To ascertain the fate of airborne contaminants as they are influenced by these factors requires a monitoring network, a modeling program, or both. Since the oil shale industry is in its infancy, a modeling program based on the expected magnitude of development and addressing the issues important to the industry is absolutely necessary, both for practical considerations and due to the regulations contained in recent amendments to the Clean Air Act. The models resulting from such a program can be used in assessing the impacts of the expanding industry, in plant-siting analyses, in urban and other land-use planning, and for instructional and scientific purposes.

In constructing an air quality simulation model (AQM), we must know the chemical species that are to be simulated, the space and time domains, model time and space increments, and the pollutant concentration levels of interest. This information is integrally related to the air quality issues that face the growing oil shale industry. These issues are briefly outlined in the following paragraphs.

TABLE 4. Some of the Best-Known Retorting Technologies Applicable to Western U.S. Shales [14]

Method	Description
Bureau of Mines Surface Retort	Authorized in 1944, this retort was later built at Anvil Points near Rifle, CO. Crushed shale moves down the vertical, kiln-like vessel by gravity and hot, recycled gases move up from the bottom. The combustion of gases and some carbon from the processed shale results in rising hot gases that heat the raw shale to retorting temperature. The oil vapor and gases rise to the top of the retort and are removed.
Paraho Surface Retort	This is a vertical, steel vessel, in which lumps of shale, 3 in. and smaller in size, enter as feed at the top of the kiln and descend by gravity against hot rising gases. The shale vapors rise to the top of the retort for removal, and processed shale cools and leaves through a moving grate in the bottom, in essentially the same size as when it entered.
Lurgi-Ruhrgas Surface Process	The distinguishing characteristic of Lurgi is that a solid heat carrier, such as hot sand or fine-grained retort residue, is mixed with 3/8-in. shale in a horizontal screw mixer.
TOSCO II Surface Retort	Developed by the Tosco Corp., this retort is not a gas-combustion process. Rather, it's a rotary-type retort that uses hot ceramic balls, at a temperature of at least 900°F, to heat the shale.
Union Oil Surface Retort	The Union upflow retort features a rock pump with a 10-ft-diameter piston. It moves crushed oil shale upward into the retort where crude shale oil is produced in both gaseous and liquid form. Heated gases enter at the top of the retort and flow down. Shale oil is taken from the bottom of the retort.
Petrosix Surface Retort	Currently in operation in Brazil, Petrosix is a variation of the gas-combustion retort. A major modification in this process is the use of reheated and recycled gas.
Circular Grate Surface Method	This method can process oil shale containing dawsonite, and when extracting the oil produces a soluble form of aluminum. The circular grate rotates inside a retort shaped like a giant doughnut and carries shale through several processing zones in the retort.

TABLE 4. (contd)

Method	Description
In-Situ Processes	True in-situ retorting takes place totally underground and requires no mining. Boreholes are drilled into the deposits, so the shale can be fractured into small fragments underground. The oil and gas are produced by various means depending on the retorting technique. In some processes, combustion takes place; in others, super-heated steam or microwaves heat the structure to retorting temperature. Oil and gas then flow through fractures in the deposit.
Geokinetics, Inc. Horizontal In-Situ Drilling Process	The horizontal in-situ method is being tested in the shallow deposits of the Uintah Basin of Utah. and blasting the oil shale creates the void needed for the retort, and holes are drilled in both ends for air injection and oil and gas extraction. (The Laramie Energy Technology Center has been working on a process that allows retorting to proceed in virtually any direction.)
Modified In-Situ (MIS) Processes	Modified in-situ combines mining and true in-situ processing. One technique is to create voids by removing 20-30 percent of the shale and hauling it to the surface for above-ground retorting. When an adequate void has been created, explosives are used to fracture the remaining oil shale, which is retorted (underground). One such technology is the Occidental modified in-situ method tested at Oxy's privately held site at Logan Wash, CO. Since 1972, this method has produced more than 100,000 barrels of shale oil for research. Rio Blanco Oil Shale Co. has also tested it own MIS technology on tract C-a.

The Clean Air Act

The essential features of the Clean Air Act that impact the development of the oil shale industry are the National Ambient Air Quality Standards (NAAQS), the Prevention of Significant Deterioration (PSD) regulations, air monitoring requirements, visibility regulations, and air quality related values (AQRV) over and on Class I PSD areas. More explicitly, these features are:

- National Ambient Air Quality Standards

  These primary and secondary standards are set for individual (criteria) pollutants and reflect both impacts from short-term and long-term exposures to the contaminants. The criteria pollutants are suspended particulate matter, sulfur oxides, carbon monoxide, nitrogen oxide, ozone, nonmethane hydrocarbons, and lead [15].

- Prevention of Significant Deterioration

  Federal PSD regulations are designed to protect areas (Class I and II areas for the oil shale region) that are currently in compliance with federal primary NAAQS from further significant deterioration. Regulations have been promulgated for suspended particulate matter and sulfur dioxide for both short-term and long-term exposures [15].

- Monitoring

  Monitoring of plant emissions is currently a requirement of the PSD program and may become necessary to estimate visibility impairment. The EPA has regulatory authority to require inclusion of certain pollutants in an oil shale developer's monitoring program. In its environmental advocacy role, EPA also has an interest in characterizing quantities of other pollutants released and their resulting impacts, see Table 5 and References [7,16].

- Visibility

  In the 1977 Amendments to the Clean Air Act, Congress recognized the importance the public attaches to aesthetics such as good visibility. Congressional intent was to protect our visibility heritage, and to ensure that we will be able to pass it on to future generations. EPA promulgated final regulations for plume blight on December 2, 1980. Plume blight is defined as an identifiable, coherent plume which is perceivable against the background sky. Plume blight is generally traceable to a source and is primarily caused by the scattering of light by aerosols and the selective absorption of blue light by nitrogen dioxide (NO_2).

TABLE 5. Federal monitoring guidelines under PSD. Atmospheric monitoring program pollutant components [7].

Regulatory Requirements

- Total Suspended Particulates (TSP)
- Sulfur Dioxide (SO_2)
- Nitrogen Oxides (NO_x)
- Carbon Monoxide (CO)
- Nonmethane Hydrocarbons (NMHC)
- Ozone (O_3)
- Lead (Pb)
- Sulfuric Acid (H_2SO_4) Mist
- Total Residual Sulfur [including Hydrogen Sulfide (H_2S)]
- Asbestos
- Beryllium (Be)
- Mercury (Hg)
- Fluorides (F)
- Vinyl Chloride

Regulatory Requirements of Primary Interest

- TSP
- SO_2
- NO_x
- O_3
- Pb
- H_2S
- Hg
- F

Advocated Characterization

- Inhalable Particulate (<15 μm dia.)
- Fine Particulate (<2.5 μm dia.)
- Carbonyl Sulfide (COS)
- Carbon Disulfide (CS_2)
- Sulfhydryl Compounds (RSH)
- Ammonia (NH_3)
- Arsine (AsH_3)
- Selenium (Se)
- Sulfates ($SO_4^=$)
- Nitrates (NO_3^-)
- Cadmium (Cd)
- Radioactivity
- Polycyclic Organic Matter (POM)

- Fugitive Dust

  Rather than being a specific regulated quantity, fugitive dust is an emission type (a subcategory of total suspended particulates) that is regulated through existing standards. Fugitive dust has been defined as "particulate matter" composed of soil that is uncontaminated by pollutants resulting from industrial activity. Fugitive dust associated with oil shale production results from mining, transporting of both overburden and shale ore, crushing and grinding of the ore, and ultimately the disposal of the processed shale.

- Air Quality Related Values

  The Flat Tops Wilderness Area (Figure 7) is a mandatory federal Class I PSD area under the jurisdiction of the U.S. Forest Service Federal Land Manager (FLM). The FLM uses the Class I increments as guides to the determination of any adverse impact on air quality related values (AQRV) of this Class I area. While the increments apply to particulate matter and SO_2, AQRVs are protected against any pollutants. The AQRVs for the Flat Tops Wilderness Area (visibility, soil-water, fish and wildlife, and vegetation) may be impacted by a combination of existing and future facilities, such as coal mining facilities, coal-fired power plants, increased mineral activity (uranium mining, etc.), and oil shale processing facilities [17].

Potential Regulatory Activity

Regulatory activity that may be formulated and promulgated in the future includes changes or additions to the NAAQS, phase II visibility regulations, PSD Set II regulations, and acid precipitation. For example, we may have:

- NAAQS Changes or Additions

  Many of the NAAQS may be changed in the near future. Of these changes, the addition of a short-term NO_2 standard and a fine particulate standard seem to be the most imminent. The fine particulate standard may be two-fold: a standard for particles less than 2.5 μm in diameter to protect human health and indirectly produce some measure of visibility protection; and a standard for larger particles, possibly for diameters less than 10 μm. These particulate standards would replace the TSP standard and probably affect the type of controls used on certain pollutant sources. In addition, these standards may have the effect of moving many of the fugitive dust problems out of the "ambient air" regulatory control area.

- Visibility Regulations for Regional Haze

  Although EPA has not yet formulated the regulations, Phase II of the visibility program will address the additional controls needed to mitigate long-range visibility impacts such as regional haze. Regional or general haze, which can occur over hundreds of kilometers and last for days, is produced by multiple sources which are not easily identified. The haze is caused by fine particles (sulfates, nitrates, organics) which scatter light and reduce apparent contrast. Phase II regulations have the potential to limit oil shale development.

- PSD Set II Regulations

  The 1977 Amendments directed EPA to conduct a study and by August 1979 promulgate regulations to extend the PSD framework to cover hydrocarbons, carbon monoxide, photochemical oxidants, and nitrogen oxides. Such regulations were to become effective one year later and were to call for revisions of existing state implementation plans during the next subsequent year. However, this schedule has not been met. Thus, for the next few years the PSD program will continue its current focus on particulates and sulfur dioxide. But the analysis of anticipated emissions to determine whether a new source is subject to PSD review will be made in reference to any pollutant regulated by the Clean Air Act.

- Acid Precipitation Regulations

  The Acid Precipitation Act of 1980 (Title VII of the Energy Security Act of 1980 - P.L. 96-294) established the interagency Task Force on Acid Precipitation to develop and implement a coordinated National Acid Precipitation Assessment Program. The act mandates that the task force produce a National Plan for a ten-year program [18]. The purpose of the program is to identify the sources, causes and processes involved in acid precipitation and to evaluate the environmental, social, and economic effects of acid precipitation. To date, no legislation or regulatory action has explicitly been taken to reduce the impact of acid precipitation. However, when or if such action occurs, it will most likely affect shale oil development, although the magnitude of that impact is highly uncertain.

State Regulations

The current state ambient air quality standards for Wyoming, Colorado and Utah are given in [19]. The Colorado standards are more restrictive than the NAAQS for certain categories of SO_2, and Wyoming standards are more restrictive than the NAAQS for certain categories of SO_2, particulates and oxidants, while the Utah and federal standards are identical for the categories regulated.

In addition to ambient air quality standards, certain states have promulgated pollutant emission standards. For example, the state of Colorado has developed a regulation restricting SO_2 emissions to .3 lb. of SO_2 per barrel of shale oil produced. The goal of the legislation, according to the state, is two-fold. First, the legislation attempts to protect air quality while at the same time permitting development of a shale oil industry. Second, by placing a limit on emissions per unit of production, the regulation hopes to encourage efficient control technology, and thus clean production processes. Although above-ground oil shale retorting can meet the .3 lb/barrel limitation, modified in-situ (MIS) developers may have some problems.

Hazardous and Toxic Substances

The spectrum of compounds generated as a result of producing shale oil from the formations in Utah-Colorado and the hazards produced by these compounds are considerably different than those found in the normal crude petroleum industry. For example, shale oil contains much higher concentrations of nitrogen-containing compounds, PAH's, and phenols than do the products from crude oil. In addition, mine safety is a concern in the oil shale industry but not in crude oil processing. For example, quantification of radionuclide emissions and the explosivity of oil shale dusts are important considerations.

Classes of compounds, excluding the criteria pollutants, that are of particular concern from an environmental and health effects standpoint include [20,21]:

- Methane in oil shale mines.
- Naturally occurring radionuclides and silica in oil shale dust and associated fugitive dust.
- Gaseous ammonia, H_2S and volatile organics that my be released during moisturizing and subsequent cooling of retorted shale.
- Polycyclic organic material (POM) and certain trace metals from fuel combustion and fugitive dust from spent shale handling and disposal.
- Reduced species of nitrogen and sulfur formed and distributed in shale, oil and gas.
- Volatile trace elements, (i.e., mercury, arsenic and selenium) that are released in offgases from retorts.
- Carcinogens that are formed in product oil and gas, especially aryl amines, nitrogen heterocycles and PAH.

Bates and Thoem [7] state that no population exposure or worker dose calculations for radionuclides, due to the uranium and thorium content of oil shale, have been made for the purpose of projecting health effects of oil shale development. However, estimates have been made that indicate that population exposure doses of radionuclides due to the extraction of shale oil are relatively insignificant compared with geothermal utilization and coal combustion, liquefaction, and gasification.

Atwood et al [22] studied the fire and explosive potentials of oil shale dust. They found that the ignition and explosivity properties increased as the organic content of the oil shale dust increased and as the particle size decreased. However, oil shale dusts were shown to be much less explosive than coal dusts.

Secondary Impacts and Climate Changes

The oil shale region is sparsely populated and consists primarily of agricultural and mining based communities. However, with a growing energy industry (oil shale, coal-fired power plants, coal mining, coal conversion, oil and gas production, and uranium mining and processing), the existing and new communities (e.g., Battlement Mesa, CO) in the Utah-Wyoming-Colorado Green River Formation area are expected to grow rapidly over the next several years [10,23,24,25].

This increased population and the accompanying development will create additional sources of air pollution -- called secondary impacts. The secondary sources of pollutants include:

- automobiles and trucks -- within urban areas and along interurban corridors.
- airplanes, airports, trains and rail lines
- construction vehicles
- residential home heating
- commercial and institutional heating
- indirect sources such as hospitals, shopping centers, sport complexes, and power plants.

The pollutants that will be emitted from these sources are generally those that already fall under federal regulations.

Because of the tendency to burn wood in mountain valley communities, there is a potential for serious impacts from this activity. Recently completed studies [26,27] have shown that emissions of particulate matter (sizes < 2 μm in diameter), CO, and condensable organics (i.e., POM) are relatively high from residential woodburning stoves and fireplaces when compared to emissions from residential gas-and oil-fired furnaces. In some

Colorado communities there are currently regulations limiting the number of wood-burning stoves or fireplaces.

The rapidly growing communities in the oil shale region may modify local weather and climate [28,29]. For example, visibility may decrease in the mountain valleys, haziness and cloudiness may increase, precipitation and thunderstorm activity may be modified, temperature and wind fields will be changed over the urban areas, and fog and humidity may increase. However, whether or not the Utah and Colorado communities experiencing growth due to a mature oil shale industry will adversely affect local climate and weather will require future monitoring of these communities, as well as modeling studies.

The only major global climate changes that could be attributable to a large oil shale industry are those that result from a buildup of atmospheric carbon dioxide (CO_2) concentrations. Carbon dioxide concentrations in the atmosphere of the world have been increasing for some time. In July 1979, the National Research Council of the National Academy of Sciences convened a study group to assess the scientific basis for projection of possible future climatic changes resulting from man-made releases of carbon dioxide into the atmosphere. The report on that study noted [30]:

> We now have incontrovertible evidence that the atmosphere is indeed changing and that we ourselves contribute to that change. Atmospheric concentrations of carbon dioxide are steadily increasing, and these changes are linked with man's use of fossil fuels and exploitation of the land. Since carbon dioxide plays a significant role in the heat budget of the atmosphere, it is reasonable to suppose that continued increases would affect the climate.

Estimates are that a global synthetic fuels production of 5 to 6 million barrels per day oil equivalent over the next 20 years could add 2 to 3 ppm CO_2 to the atmosphere by the year 2000 [31], and it might produce an increase of 20 ppm by the end of 50 years of production [32]. However, most investigators seem to agree that a six million barrel per day additional synfuel capacity will have a trivial effect on the CO_2 concentrations when added to the present world mix of fossil fuels. There should be no detectable difference in the climate from these additions [33].

AIR QUALITY MODELING

The family of air quality models (AQM) is concerned with atmospheric processes in the planetary boundary layer (the first kilometer or so over simple terrain, and possibly the first 3 or more kilometers over complex terrain) and how these processes govern the transport and fate of contaminants in this layer. The members of this family are differentiated from one another by the manner in which they treat or address certain characteristics and elements, see Figure 12. These components and the data required to drive and evaluate the AQM's are discussed in the following paragraphs.

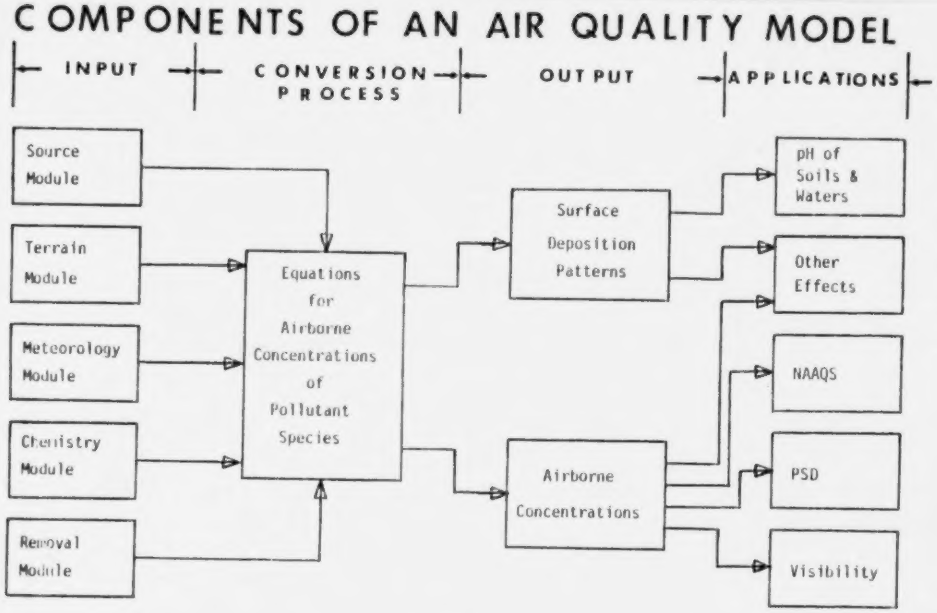

COMPONENTS OF AN AIR QUALITY MODEL
INPUT
CONVERSION PROCESS
OUTPUT
APPLICATIONS
Source Module
Terrain Module
Meteorology Module
Chemistry Module
Removal Module
Equations for Airborne Concentrations of Pollutant Species
Surface Deposition Patterns
Airborne Concentrations
pH of Soils & Waters
Other Effects
NAAQS
PSD
Visibility

Figure 12. The components of an air quality model, without interactive coupling with the atmospheric variables.

Dependent Variables

The dependent variables in AQM's consist of primary pollutants, secondary pollutants, and possibly meteorological parameters.

- Primary pollutants are the direct emissions of gaseous and particulate species.
- Secondary pollutants are the intermediate and final chemical species produced in the ambient air.
- For coupled systems the atmospheric variables, such as wind and temperature fields, the phases of water, and the temperature and moisture fields of the solid or liquid earth, are considered.

Domain of Computation and Model Resolution

- Temporal and spatial domains of computation are functions of the problem or issue, the scales of the important meteorological processes, the scales of landforms of interest, and the rates of reaction of the chemical species.
- Classification of horizontal domains can be given as ---

  microscale (1 km or less),

  local (1 km to 10's of km),

  mesoscale (10's km to 100's km),

  regional (100's km to 1000's km),

  global (1000's km to the globe).
- Classification of dimensionality can be given as --- well-mixed (a box of well-mixed pollutants), one-dimensional (horizontal or vertical), two-dimensional (vertical and horizontal), and three-dimensional.
- Classification of temporal domains can be given as --- time-evolving (continuous evolution with time), steady-state (no evolution in time), and time-averaged (evolution in discrete time steps).
- Classification of coordinate systems can be given as --- Eulerian (system fixed at some point on the earth's surface), Lagrangian (system fixed to a moving air parcel or cloud of pollutant), Mixed (combination of Eulerian and Lagrangian systems).

- Minimum horizontal space grid should be about 1/100 of the horizontal extent of the domain; vertical grid should be based on about 20 grid spaces, with finer meshes closer to the ground; and the time increment should be from seconds to minutes for microscale domains, several minutes to an hour for local scale, 1 to 2 hours for mesoscale, 2 to 6 hours for regional, and 6 hours to a day for global.

Source Module

- Considers manmade and natural sources of pollutants.
- Considers pollutants transported into the domain of computation from outside the domain.
- Considers resuspension of particulate and reemission of gaseous material.
- Identifies source locations and characteristics and emission factors.
- Identifies local meteorological conditions affecting the emissions (such as factors affecting plume rise).
- Identifies local terrain conditions affecting the emissions (such as factors affecting wake effects, stack and terrain downwash).

Terrain Module

- Gives the elevation of the terrain based on the spatial resolution of the model.
- Locates important landforms and bodies of water.
- Identifies surface roughness, land-use, and surface albedo.
- For uncoupled models, addresses the air/land and air/water heat and moisture balances.

Meteorology Module

- Accounts for the temporal and spatial distributions of wind speed and direction, atmospheric pressure and density fields, and solar and terrestrial radiation balances.
- Accounts for the temporal and spatial distributions of the temperature and stability structures of the atmosphere.

- Determines the diffusive and mixing potential of the atmosphere.

- Addresses the atmospheric humidity, and cloud and precipitation systems.

Chemistry Module

- Considers the changes in primary and secondary pollutant concentrations due to homogeneous and heterogeneous thermochemical reactions, photochemical reactions, and gas-to-particle conversion processes.

- Considers the evolution of aerosol populations due to gas-particle and particle-particle interactions.

Removal Module

- Considers the dry removal of airborne gases and particles by impaction, absorption, and chemical interactions with various surfaces.

- Considers the wet removal of airborne gases and particles by rain, snow and fog.

Governing and Auxiliary Sets of Equations

- Based on the conservation of mass equations for the primary and secondary airborne pollutants of interest.

- Contaminant equations are usually uncoupled from the atmospheric field equations in the sense that the pollutant concentrations do not affect the wind, temperature and water fields of the atmosphere. The converse is obviously untrue.

- Auxiliary equations consist of the initial and boundary conditions for the pollutant conservation equations, state and phase equations, and certain constituent equations that define system parameters.

- Solution processes should be consistent with the model's complexity and desired resolution, the available computation system, and the time and economic constraints of the investigation. The solution algorithms may be classical approximation techniques, random walk or Monte Carlo techniques, finite difference methods, or spectral and variational methods.

Output Modules

- Present the calculated airborne concentrations and surface deposition patterns of the pollutants in a meaningful and informative manner for the model user.
- Output displays may consist of numerical tables, graphs, punched cards or magnetic tapes, interactive display screens, and computer movies.

Application Modules

- The NAAQS, PSD, and some of the other effects "modules" use the output data without any major new processing taking place.
- The pH of soils and water module may be highly complex if account is made of surges of acid-laden water to lakes due to spring snow melts, or if account is made of the mobilization of certain metallic cations (i.e., aluminum) by acidic water.
- The pH module may be simple if rain water concentrations of nitrates and sulfates are crudely converted to a pH value for a precipitation event.
- The pH module may account for the interaction between acid precipitation and the mobilization in soil and water of toxic materials (i.e., magnesium, zinc, copper, boron, fluorine, bromine, cadmium and mercury) deposited by dry removal processes.
- The visibility module converts airborne concentrations of particles, NO_2 and O_3 into certain visibility measures (i.e., visual range, plume contrast, discoloration, perceptibility, and blue-red ratio) to assess the effects of plume blight, or veiled and regional haze.

Model Evaluation

The questions that the EPA Model Clearinghouse considers in its evaluation of new air quality models are:

- Is the model scientifically defensible?
- Is the model applicable to the area or type of terrain in question, and for the purpose specified?
- Is the given model better (according to some comparison criteria) than what exists?

- Do proper data bases exist to operate the model in its specified mode?

- Has the model performance been favorably evaluated (according to some evaluation criteria)?

Once the application and area of interest of a new air quality model have been specified and the criteria of model comparison and evaluation have been determined, these questions can be addressed. In answering these questions, an investigator should consider the following items:

- Sources of error

- Sensitivity tests

- Candidate field experiments or existing data sets for model operation and evaluation.

There are many sources of error in AQM's due to inaccuracies in laboratory and field measurements, poor numerical solution techniques, errors in computer programs, and incorrect or poor physical approximations. A technique for assessing the importance of these modeling errors is to run a series of model sensitivity tests. These tests are conducted to assess the changes in the model output due to changes in input data, system parameters, boundary and initial conditions, and reaction mechanisms. The tests should be conducted in a one-by-one fashion and also in a manner to account for the synergistic effects among the errors in two or more of the variables or parameters.

Verification or validation tests are "hands-off" comparisons between model outputs and comprehensive field data sets. The data sets must be independent of but consistent with the data used to run the model and evaluate initial and boundary conditions and system parameters. The objectives of model validation are to establish by statistically rigorous procedures the reliability and accuracy of the model predictions, the range of applicability of the model at a given site and its transferability from site to site, and to delineate the areas of uncertainty in the model predictions.

Many standard statistical tests are available to evaluate the performance of models against observations. Some of these tests are correlation methods, spectral and frequency methods, and pattern recognition.

Once the model has been thoroughly tested it should be completely documented. Protocols and standards for model documentation should address the following items: the explanation of the conceptual basis of the model, the limitations of the model, the precision of the model, level of model validation, the basic information on the computer programs, and the operating instructions for the model.

Data Needs

The data requirements to operate and evaluate air quality models are highly variable. These requirements are a function of the air quality issue being addressed, the model and its component parts, the local and mesoscale terrain, the background concentrations of pollutants, the time and space scales of interest, and the time, space, and concentration resolution requirements. At present, there is no adequate set of data to operate and evaluate mesoscale air quality models, especially over a region as complex as the Utah/Colorado oil shale area.

Guidelines for data requirements have been given in many reports [34 to 39]. As an example, we give the summary from [34]:

- Siting Data

  Relative to a common reference map the following field sites must be accurately located:

  --- Every stack (and other significant source)

  --- Every meteorological monitor

  --- All ambient air monitors.

- Wind Field Data

  For the majority of applications, the following wind data will provide input from which an adequate wind field can be generated.

  --- Several ground-based sites monitoring hour-averaged wind speed and wind direction

  --- One or more (depending on terrain complexity) sites monitoring hour-averaged vertical wind profiles

  --- A detailed topographic map of the study region.

- Dispersion Data

  Hourly vertical temperatures profiles at one or more (depending on terrain complexity) sites should be compiled. Understanding of the dispersion would be greatly enhanced if hour-averaged ground-level temperatures were recorded at each monitoring site.

- Source Data

  For each stack the following data should be recorded as hour averages as appropriate:

  --- Height (meters)

  --- Diameter (meters)

--- Gas temperature (degrees C)

--- Gas volume flow (m^3/sec)

--- Pollutant emission rates of stack gas constituents (g/sec)

--- Ambient air temperature (degrees C).

- Pollutant Data

  The pollutants of interest should be measured at one or more (depending upon terrain and source distribution complexities) sites. At each site a record should be made from which an hour average can be calculated.

- Chemistry Data

  Field programs designed to study the impact of a plume on chemically active pollutants should compile an emissions inventory, record background pollutant levels and initial concentrations as well as acquiring the following hourly data:

  1. Ozone Simulation

     --- Solar ultraviolet radiation (watts/m^2)

     --- Concentrations of water vapor (ppm)

     --- Concentrations of O_3, NO, NO_2, CO and reactive hydrocarbons (ppm).

  2. Sulfur Simulation

     --- Concentrations of SO_2, $SO_4^=$ and water vapor.

- Removal Data

  Collect event, seasonal and annual data on

  --- Surface roughness and cover

  --- Land use, current and future

  --- Storm types, frequencies, intensities, time histories, and trajectories.

SECTION 5

IDENTIFICATION AND EVALUATION OF DATA AND INFORMATION SOURCES

We believe that theoretical, laboratory, field and simulation studies all contribute to the data and information required to understand and predict the origin and fate of airborne pollutants over any given region of the country. And we further believe that if the various studies are properly conceived and performed and their results are adequately archived and reported, then the information and data generated for or collected at a given place and for a given purpose can be partially or wholly transferred to another place. It was with this conviction that the information and data identified in this report were collected during the first years of the Green River Program. The contents, as outlined in the Introduction, of the annotated bibliography in Appendix A and the bibliography in Appendix B are a result of this activity. However, the information and data sources listed in these two appendices have not been thoroughly analyzed, and thus a comprehensive synthesis of the material has not been made for application over the Utah-Colorado-Wyoming oil shale area. We believe this type of synthesis is very necessary if the currently available information and data are to be efficiently used and future studies over the oil shale areas are to be economically planned and performed.

The purpose of the present section of this report is to identify and evaluate, at least in a cursory manner, the information and data that we have collected for the mesoscale domain containing the oil shale deposits of Utah-Colorado-Wyoming. The categories of information and data are:

- Terrain Data
- Emission Data
- Meteorological Data
- Air Quality Data

TERRAIN DATA

The terrain data (see Section 4) that are important in air quality analyses are: elevation of the terrain, location of important landforms and bodies of water, surface roughness and land-use, surface albedo, and air/land and air/water heat and moisture balances.

Elevations, Landforms and Water Bodies

Terrain elevations, landforms and water bodies can be easily identified from USGS contour maps and digital terrain tapes. Figure 13 indicates the 1:250,000-scale contour maps that cover the mesoscale domain defined in Figure 2. These topographical maps have sufficient resolution for mesoscale modeling and reasonably good resolution for most local modeling. The digital terrain tapes, publicly distributed by the National Cartographic Information Center of Reston, Virginia, cover this same area with a resolution as fine as 60 meters in the horizontal [40].

The importance of the horizontal grid resolution for the Utah-Colorado oil shale area can be easily demonstrated by Figures 14 and 15. The horizontal resolution of the terrain profiles in these figures is about one kilometer. With this resolution, the deep creek and river canyons are well-defined in Figures 14b and 15a. However, if this terrain is smoothed with a 3 to 10 kilometer filter, many of the important valleys would disappear. Hence, mesoscale modeling over this region, as one follows pollutants from the Piceance Basin to the Flat Tops Area, presents many challenges to the investigator. Many of these challenges are terrain oriented, and thus require well-defined topographical information.

Surface Roughness, Land-Use, Surface Albedo

Surface roughness and land-use data are required in various air quality related calculations, such as vertical wind profiles in the planetary boundary layer, dry removal parameters, and surface albedo determinations in radiation balance computations. These data can be obtained from a combination of maps and figures:

- The topographical maps and digital terrain tapes discussed in the previous subsection.
- The geographic and land-surface form maps given in Appendix C.
- The terrain profiles (with a variety of horizontal grid resolutions) given in Figures 14 and 15 and Appendix C.
- Land-use and soils maps developed by the U.S. Soil Conservation Service for the various states in question, see [41] for Wyoming, [42,43] for Colorado, and [49,50] for Utah.
- Land-use and ground cover maps developed by various state agencies, such as the Colorado maps for existing land-use and snow depth [44].
- Vegetation and land-use maps developed for special areas in the states, such as

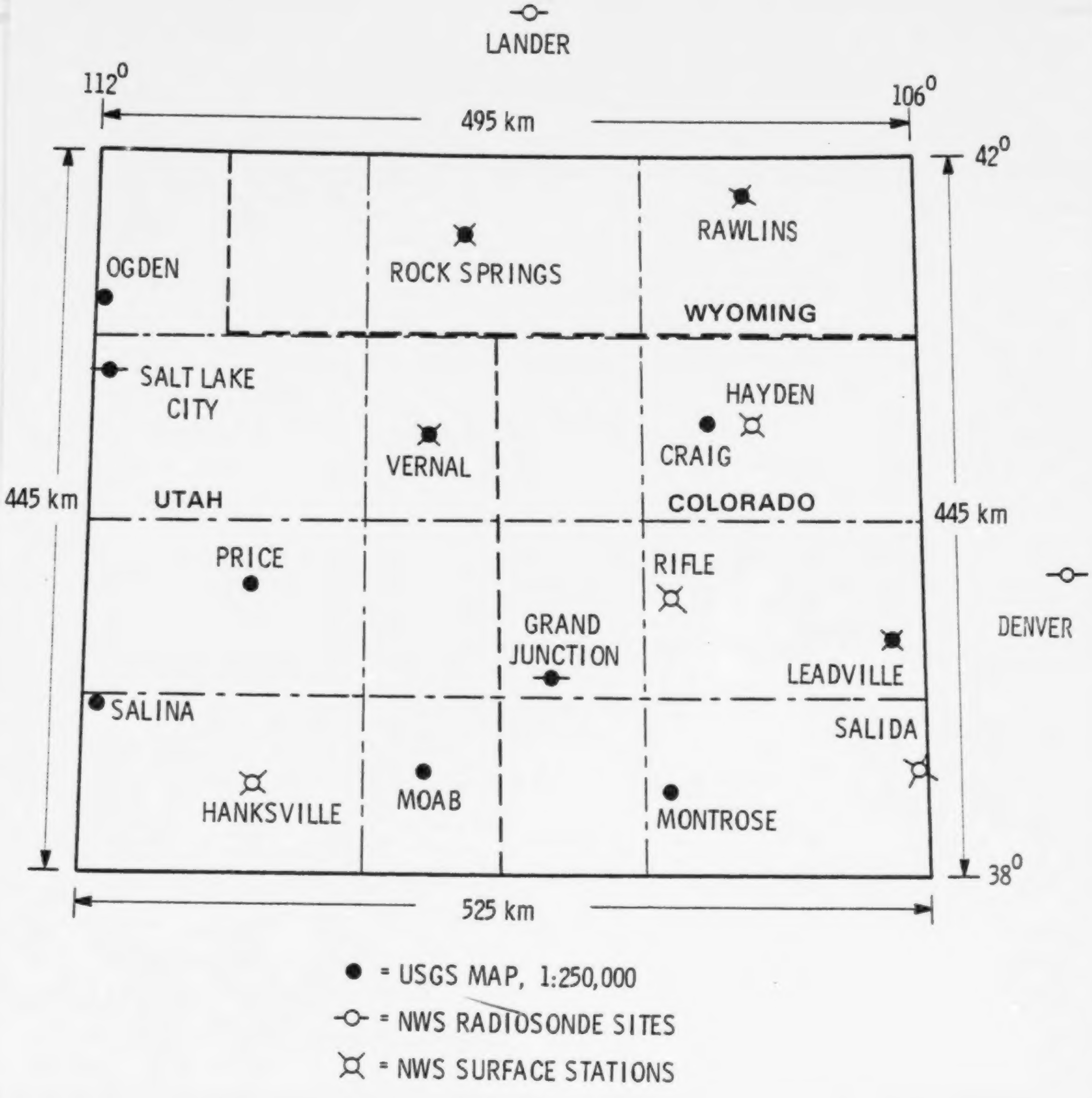

LANDER
112°
106°
495 km
42°
ROCK SPRINGS
RAWLINS
OGDEN
WYOMING
SALT LAKE CITY
HAYDEN
VERNAL
CRAIG
445 km
UTAH
COLORADO
445 km
PRICE
RIFLE
DENVER
GRAND JUNCTION
LEADVILLE
SALINA
SALIDA
HANKSVILLE
MOAB
MONTROSE
38°
525 km
● = USGS MAP, 1:250,000
-○- = NWS RADIOSONDE SITES
⌧ = NWS SURFACE STATIONS

Figure 13. The USGS contour maps, 1:250,000, that cover the mesoscale domain. The locations of the four upper-air NCC stations (Salt Lake City, Lander, Denver, Grand Junction), and several surface NCC stations are also shown.

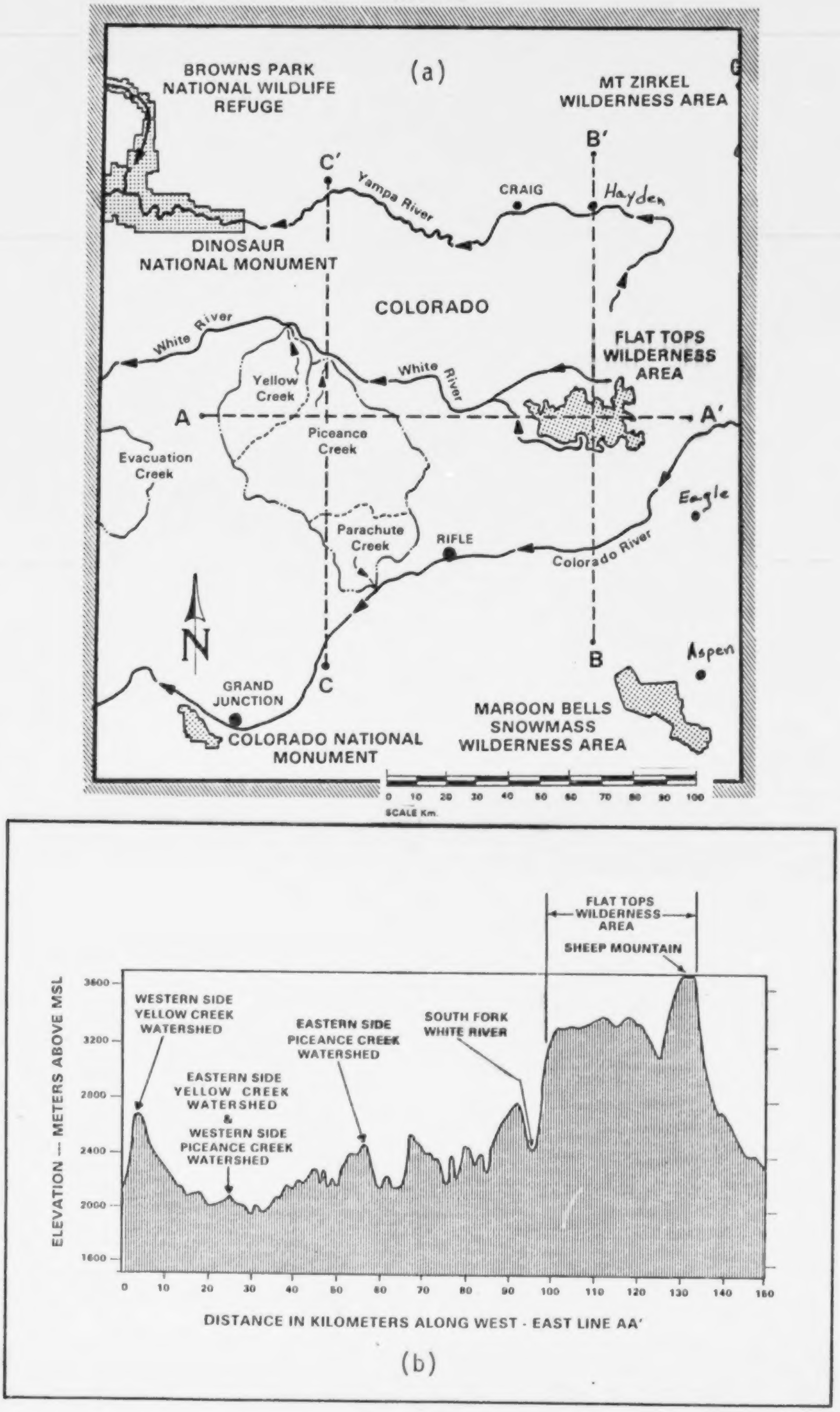

(a)
BROWNS PARK NATIONAL WILDLIFE REFUGE
MT ZIRKEL WILDERNESS AREA
B'
C'
Yampa River
CRAIG
Hayden
DINOSAUR NATIONAL MONUMENT
COLORADO
White River
Yellow Creek
White River
FLAT TOPS WILDERNESS AREA
A
A'
Piceance Creek
Evacuation Creek
Eagle
Parachute Creek
RIFLE
Colorado River
N
B
C
Aspen
GRAND JUNCTION
MAROON BELLS SNOWMASS WILDERNESS AREA
COLORADO NATIONAL MONUMENT
0 10 20 30 40 50 60 70 80 90 100
SCALE Km
FLAT TOPS WILDERNESS AREA
SHEEP MOUNTAIN
WESTERN SIDE YELLOW CREEK WATERSHED
EASTERN SIDE PICEANCE CREEK WATERSHED
SOUTH FORK WHITE RIVER
EASTERN SIDE YELLOW CREEK WATERSHED & WESTERN SIDE PICEANCE CREEK WATERSHED
ELEVATION — METERS ABOVE MSL
3600
3200
2800
2400
2000
1600
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
DISTANCE IN KILOMETERS ALONG WEST - EAST LINE AA'
(b)

Figure 14. (a) The Piceance Basin of Colorado and the Flat Tops Wilderness Area. (b) Terrain profile along the west-east line segment AA'.

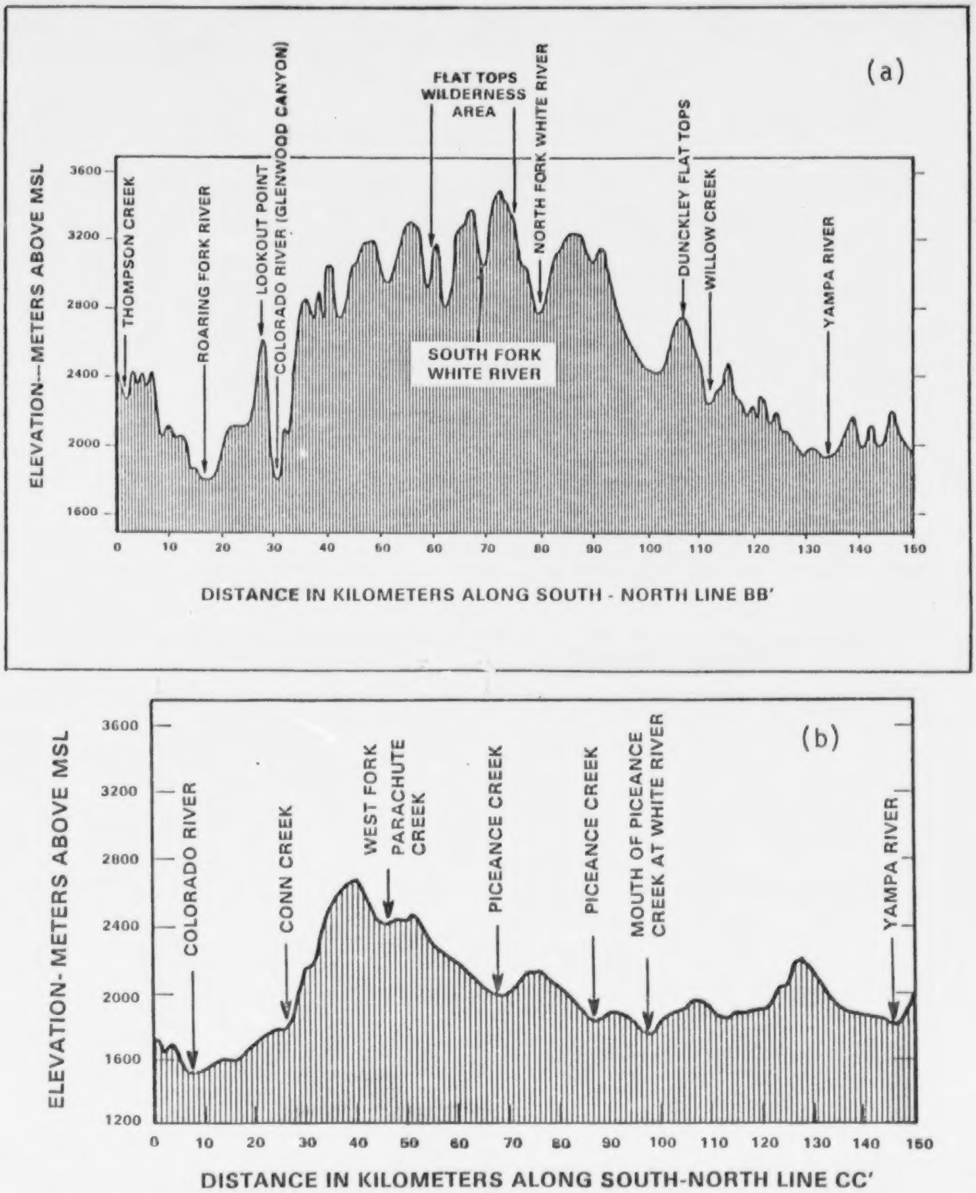


Figure 15. (a) Terrain profile along the south-north line segment BB' of Figure 14a. (b) Terrain profile along the south-north line segment CC' of Figure 14a.

-- Vegetation map for the Piceance Basin [45],

-- Land-use and plant communities in Garfield County, CO [46],

-- Visitor's map for the White River National Forest [47],

-- Visitor's map for the Flat Tops Wilderness Area [48],

-- Utah-Colorado oil shale site contour maps [51].

As mentioned above, the surface albedo is related to the surface roughness and land-use data. In addition, surface albedo depends on the ground cover, which varies with the seasons. Some of the maps listed above will help in determining these seasonal changes. In addition, certain satellite data will be useful in these determinations, especially the data from the LANDSAT series.

Air/Water and Air/Land Heat and Moisture Balances

The heat and moisture balances between the air and land and water surfaces are required for radiation balance calculations and for characterizing the flow and temperature fields in the planetary boundary layer. Data for heat and moisture balances have usually been obtained as an integral part of the studies concerned with the dispersion of pollutants under various meteorological regimes. The studies collecting such information will be discussed in the later subsections of this report.

EMISSION DATA

Atmospheric emissions will occur from each stage, or unit operation, of the shale oil fuel cycles shown in Figure 9. Since the activities at a given stage differ from the activities in the other stages, the emission characteristics and pollutant species also differ. See Table 6.

Emissions of Trace Elements

The trace elements and their emission source strengths, indicated under retorting operations in Table 6, are highly process oriented. However, most metallic and heavy elements in the oil shale are not vatatilized since the temperatures and oxidation-reduction conditions during retorting are not severe enough. With notable exceptions, such as mercury, arsenic, selenium, and possibly cobalt, ontimony and nickel, the trace elements will remain with the spent shale or will be found as components of raw and spent shale solids entrained in retort gases and in raw shale oil. The arsenic in the raw shale apparently forms a range of volatile oil-soluble compounds (i.e., organic arsines) during retorting. These compounds appear in raw shale oil and in all condensible oil fractions. If they are not removed during upgrading, arsenic will be present in shale oil combustion products [7,21].

Table 6. Sources and Nature of Atmospheric Emissions from Oil Shale Extraction and Processing [7,10,20,21,22,52 to 57].

Unit Operations	Emissions Generating Activity	Potential Criteria Pollutants	Potential Noncriteria Pollutants
Oil Shale Extraction	Blasting, Fugitive Emissions, Fuel use in Equipment	Particles, CO, NO_x, HC's, SO_2, Pb salts	Hg, Silica, Methane
Raw Shale Transport	Fugitive Emissions, Fuel Use in Equipment	Particles, CO, NO_x, SO_2, HC's	Silica, Polycyclic Organic Material (POM)
Shale Preparation	Crushing, Screening, Ore Storage	Particles	Silica
Retorting Operations	Fugitive Emissions, Fuel Use, Combustion of Shale Organic Material, Spent Shale Discharge	Particles, CO, NO_x, SO_2, HC's	Trace Elements, Trace Organics, H_2S, NH_3, CS_2, Volatile Organics, COS
Upgrading and Utility Operations	Fuel Use, Fugitive Emissions	Particles, CO, NO_x, SO_2, HC's	H_2S, CS_2, COS, NH_3
Gas Cleaning Systems	Sulfur Recovery and Tail Gas Cleanup, Hydrogen Production and CO_2 Removal, Fuel Use	SO_2, Particles, CO, NO_x, HC's	CS_2, COS,
Product Storage	Tank Evaporation	HC's	--
Solid Waste Disposal	Fugitive Emissions, Fuel Use in Equipment	Particles, CO, NO_x, SO_2, HC's	Trace Organics, POM, Metals (Ni, Cr, Fe, Mo)

The emissions of nonvolatile trace elements will be in approximate proportion to raw and retorted shale particulate emissions from extraction and retorting. These emissions may not be different in nature or magnitude from those associated with the extraction and processing of other fuel and nonfuel minerals, such as limestone, coal, and phosphate rock. Further, the dolomitic or allsoline nature of western oil shale immobilizes many elements as relatively inert oxide, carbonate, or silicate salts [7].

Some radioactivity will be released to the atmosphere during oil shale mining and processing. Radioactive elements, such as thorium, uranium, potassium, and their daughters, will be contained in dust emissions, fine particulate emissions, process water discharges, and leachate from spent shale disposal piles. In addition, radon gas will be released directly from the mining operations.

Estimates of Source Strengths

Since there are no full-scale commercial shale oil operations in the U.S., emission from future facilities must be estimated from data on other industrial emissions, or on data from oil shale pilot plant and demonstration tests. Ideally, if we are given this information and we know the specific retorting process and the control technologies that will be applied to the various unit operations, the quantities of airborne pollutants produced in a future commercial-size facility can be estimated by applying realistic emission factors to the mass flow of material through the plant. Examples of these calculations can be found in the PSD and environmental permit applications submitted to the EPA by the various shale oil companies. Bates and Thoem [7] summarize the results of several sets of these calculations. Their summary tables contain emission estimates of particles, SO_x, NO_x, HC's and CO for normalized 50,000 bpd facilities. In addition, the emission tables are characterized in terms of unit operations (mining, crushing, transportation, storage and retorting) and retorting processes (TOSCO II, Paraho, Colony, Union and Occidental). Bates and Thoem also give emission data for fugitive dust, trace elements and radionuclides.

An example of a comparison between the emissions from a 50,000 bpd Colony facility and the pollutants from a 1000 MW_e coal-fired power plant is given in [58]. Thoem believes that these facilities compare on an energy basis, that is, coal input vs. oil output. The results of the comparison are:

- The Colony facility emits about 9% of the SO_2 emitted from the coal plant.
- Both facilities emit about the same amount of particulate matter.
- The Colony facility emits about 40% of the NO_x emitted from the coal plant.

Using this type of comparison as a "rule-of-thumb" will allow an investigator to relate the impacts of an expanding oil shale industry to the present and future development of mine-mouth power plants in the Rocky Mountain West.

The work of Bates and Thoem [7] plus the works of several other investigators are summarized in Table 7. This table lists the emission data sources that were used in the various investigations, and also gives the energy scenarios and meteorological data sets that were used (if pertinent).

When we compare the emission estimates from one author with those of another author in Table 7, variations are found, sometimes even large variations for the same retorting process and unit operation. These differences are probably due to one or more of the following reasons:

- Differences in the chemical nature of the shales being processed.
- The extent of on-site fuel use.
- Assumptions concerning the efficiency of control technology.
- Assumptions concerning future improvements in pollution control technology.
- Assumptions concerning extrapolation of emissions from pilot to commercial-size facilities.
- Assumptions concerning the lumping of emissions together and allowing them to be emitted from a single location and at a common time.

In summary, one thing seems certain. As better information concerning the processes and the control technology becomes known, most emission factors should decrease. An example of this is given in [7]. Figure 3-1 in [7] shows a "hyperbolic" decrease with time of the estimated sulfur emissions from a particular retorting process over the time period from 1974 to 1978.

IDENTIFICATION OF METEOROLOGICAL AND AIR QUALITY DATA

Tables 8 and 9 identify several sources of information and data on meteorological and air quality parameters in and around the Utah/Colorado oil shale areas. The data sources listed in the tables are not uniformly identified because of incomplete information given in the cited references (see column three of Table 9). Some of the data cited (such as the baseline data collected on the Federal Oil Shale Tracts U-a, U-b, C-a, and C-b) are archived in the EPA SAROAD data bank, while other sets of data may or may not be available because of company proprietory policies.

Table 8 gives the abbreviations used in Table 9 for meteorological and air quality parameters, and for station number and location. Table 9 lists the location (usually the oil shale tract) where the data were collected,

TABLE 7. Identification and Evaluation of Data and Information Sources for the Green River Formation: Source Emissions, Energy Scenarios, Meteorological Data Sets

Region of Interest	Organization	References	Source Emissions	Energy Scenarios	Meteorological Data Sets	Evaluations
Piceance Creek Basin of Colorado	U.S. Federal Energy Administration	59	Emissions based on assumed mix of retorting schemes and plant locations	Assumed two production capacity schedules	Divided annual wind fields into three regimes: gradient wind, down valley, up valley	Energy scenarios and emission estimates are dated. Meteorological data and analyses are good. They are based on NWS data and local Piceance Basin data.
Mainly the Piceance Creek Basin of Colorado. Some consideration of the Uintah Basin of Utah	U.S. Congress Office of Technology Assessment	52	Emissions based on industry estimates for the various unit operations and retorting processes	Maximum development scenario: 400,000 to 500,000 BPD in the Piceance Basin and about 500,000 BPD in the Uintah Basin	Modeling and meteorological data and information obtained from other sources	Report is a good starting point for emissions data and comparitive emissions between retorting processes. Data is somewhat dated.
Generic: Utah, Wyoming and Colorado	U.S. DOE, HEW and EPA	53 and 60	Classification of emission species	---	---	Good classification of potential species from source emissions.
Generic: Utah, Wyoming and Colorado	U.S. DOE	61	Emission factors as a function of retorting processes	---	---	Good starting point to get gross emission factors
Piceance Creek and Uintah Basins	U.S. EPA	7	Emissions based on industry estimates for the various unit operations and retorting processes	Data is mainly based on 50,000 BPD plants at the various sites	Modeling results and meteorological data taken from other sources	Report is a very good starting point for emissions data and comparitive emissions between retorting processes.
Piceance Creek and Uintah Basins	U.S. DOE	10	Emissions based on industry estimates for the various unit operations and retorting processes	High production scenario: 300,000 BPD by 1990	Taken from C-a and C-b baseline data	Report is an excellent summary of emission data. It should be consulted for regional type assessments.
States of Utah, Colorado, Arizona, and New Mexico	National Commission on Air Quality	62	Emissions based on industry estimates by site. Emissions for oil shale and power plants	High development scenario for oil shale: 939,000 BPD by 1995	Used NWS data and a set of limited fine-mesh data. Considered terrain influences	A good source of information for background pollutant sources (power plants) and mesocale meteorology.

TABLE 7. (contd)

Region of Interest	Organization	References	Source Emissions	Energy Scenarios	Meteorological Data Sets	Evaluations
Piceance Creek and Uintah Basins	U.S. EPA	63	Emissions based on industry estimates by site	High development scenario for oil shale: 880,900 BPD by 1995	Considered several modeling scenarios based on local meteorology and terrain, plume interactions, and pollutant species	A good source for modeling scenarios based on terrain and meteorology.
Piceance Creek and Uintah Basins	American Petroleum Institute	9	Production schedules and emission rates based on industry estimates	Estimated production scenario for shale oil by 1995: about 800,000 BPD	---	A good source for the industry's estimate of production and type of process, as of late 1981.
Piceance Creek and Uintah Basins	U.S. EPA	11	Emissions based on industry estimates at the sites in question	Total capacity by 1995: 1,240,300 BPD	Worst case meteolology with sector-averaged Gaussian model--accounted for drainage winds	Report presents possible scenarios of the sources impacting the various wilderness areas--good summary of worst case data.
The Six Rocky Mountain States	U.S. DOE	64, 65, 66, 67	Emissions are based on industry or DOE estimates at the sites in question	Various high, medium and low energy scenarios for the region	Use of simple Gaussian. Plumes with worst-case meteorology	Reports are good for supplying background pollution data for the oil shale region.
Various Pilot and Demonstration Plants in Utah and Colorado	U.S. DOE	20, 21, 22 55, 56	Emissions from pilot or demonstration plants, such as SO_2, H_2S, NO_x dust, POM, NH_3, and various other nigrogen, sulfur and organic species	---	---	These emission measurements and studies are good for identifying species and reactions, but not for quantifying emissions from commercial-size plants.

TABLE 8. Notation Used in Table 9

Meteorological Variables

WD = Wind direction
WS = Wind speed
W10, W20, W30, ... = Wind speed and direction at 10, 20, 30, ... meters above the ground

Temp = Temperature
Temp Diff = Temperature difference
T10, T30, ... = Temperature at 10, 30, ... meters above the ground

σ_θ, σ_ϕ, σ_W = Standard deviations of the wind

Precip = Precipitation
RH = Relative humidity
P = Pressure

SR = Solar radiation
NR = Net radiation

AR = Acoustic radar
RW = Rowinsonde

Air Quality Parameters

Part. = Airborne particles
TSP = Total suspended particulate matter
SO_2 = Sulfur dioxide
NO = Nitric oxide
NO_x = Nirtogen oxides
HC = Hydrocarbons
THC = Total hydrocarbons
CO = Carbon monoxide
H_2S = Hydrogen sulfide
O_3 = Ozone, oxidants
CH_4 = Methane
COH = Coefficient of haze
LVR = Local visual range
TM = Trace metals
VIS = Visibility

TABLE 8. (contd)

Stations/Station Heights/Station Locations

S1, S2,
S3, ... = Station number

S3---10m,
60m, 100m = Data taken of 10, 60 100 meters above the ground at Station No. 3

Locations of S1, S2, ..., S9, ..., S13 at White River

(see Figure 16)

Locations of S1, S2, S3, S4, S6, S7, S8, S9 at C-a

(see Figure 17)

Locations of S21, S22, ..., S32, ... at C-b

(see Figure 18)

Location of 1975/1976 Visibility Study in the Yellow-Piceance Creek Areas

(see Figure 19)

Location of NCC Stations in and around the Mesoscale Domain

(see Figures 20, 21, 22, 23)

TABLE 9. Identification of Data and Information Sources for the Green River Formation: Meteorological and Air Quality Parameters

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Equity - Bx 10 miles SE of C-a and 30 miles NW of C-b	Equity Oil Company	68	9/1/78 to 11/31/78	MRI Mechanical Weather Station WD, WS, temp 100 ft. Meteorological Tower WS, WD, temp at 10m and 30m, temp diff and σ_θ	---
Equity - Bx	Equity Oil Company	69	3/1/79 to 2/29/80	Ditto	---
Equity - Bx	Equity Oil Company	70	3/1/80 to 2/28/81	Ditto	---
Logan Wash near DeBeque, Co. (where Roan Creek enters the Colorado River)	Occidental Oil Shale, Inc.	71	12/1/80 to 2/28/81	S1---2m temp, RH S2---10m WS, WD, temp S3---2m temp, RH S4---2m temp, RH, SR Other rain gauges acoustic radar	S4---2m Part. Future CO, H_2S
Geokinetics See Figure 10b, 70 miles south of Vernal, Utah	Geokinetics, Inc.	72	Jan., Feb., March 1981	WS, WD, temp, snow depth at several meteorological tower locations	Process gas and stack emissions from retorts (SO_2, NO_x, HC, part, CO)
In-Situ Retorting near Rock Springs, WY	Sandia Laboratories of Albuquerque	73	---	A baseline environmental monitoring program was planned. Data source is unknown	---
In-Situ Retorting near Rock Springs, WY	Talley Energy Systems, Inc.	73	---	Meteorological Tower Data unknown	---
Naval Oil Shale Reserve near Rifle, CO see Figure 11b	Paraho Development Corporation and USGS	73	Uses unknown Paraho 3-1/2 months during 1977/1978	USGS Data temp, RH, precip Paraho WS, WD, temp 3 day tether sonde program	Paraho TSP

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Colony Parachute Creek, CO see Figure 11b	Colony Development Operation	74, 76	May-June 1972	8 nights of tracer releases in the valley. Used fluorescent dye, SO_2, silver iodide---both ground level and tower releases. Used a 200 ft instrumented meteorological tower Meterological Tower gave data at 3 levels: WS, WD, σ_θ, σ_ϕ, temp	---
Colony	Colony Development Operation	75, 76	June-July 1973	Meteorological Tower Data 7 days of tracer data from Roan Plateau, aircraft soundings, pibal tracking, no-lift balloon tracking	---
Colony	Colony Development Operation	77, 78	From 1978 and 1973 to 1975	1973-1975 S1---10m WS, WD, temp, SR S2---10m WS, WD, temp, SR S3---10m WS, WD, temp, SR From 1978 S1---10m WS, WD, precip, temp, σ_θ, σ_ϕ, SR S2---10m WS, WD, precip, temp, σ_θ, σ_ϕ S3---10m WS, WD, precip, temp, σ_θ, σ_ϕ	--- From 1978 S1---10m TSP S2---10m TSP

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Union Parachute Creek, see Figure 11b	Union Oil Co. of California	78	---	S1---10m, 60m, 100m meteorological data S2--- 10m, 60m meteorological data S3---10m, 30m meteorological data S4---30m meteorological data S5---10m, 30m, 60m meteorological data	S1---10m, 60m, 100m TSP
Chevron Parachute Creek, see Figure 11b	Chevron Shale Oil Co.	78	---	7 meteorological towers	9 TSP sampling sites
Multi-Mineral Piceance Creek, see Figure 11a	Multi-Mineral Corp.	78	---	1-10m meteorological tower	3 TSP sampling sites, 1 gaseous pollutant sampling site
Mobil Parachute Creek, see Figure 11b	Mobil Oil Corp.	78	---	2-10m towers 1-60m tower 1-100m tower for meteorological data	---
Superior Piceance Creek, see Figure 11a	The Superior Oil Co.	78	2 to 3 years of data	3-meteorological towers	1-TSP sampling site
Dinosaur NM, see Figure 7	National Park Service and EPA	78	---	WS, WD, temp	Telephotometer, contrast ratio, photographs for visibility
Canyonlands NP, see Figure 7	National Park Service and EPA	78	---	WS, WD, temp	Telephotometer, contrast ratio, photographs for visibility
Capital Reef NP, see Figure 7	National Park Service and EPA	78	---		Telephotometer, contrast ratio, photographs for visibility

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Colorado NM, see Figure 7	National Park Service and EPA	78	---	WS, WD, temp	Telephotometer, contrast ratio, photographs for visibility
Craig, CO see Figure 13	H.G. Coal Co.	78	---	WS, WD, temp	TSP
Craig, CO see Figure 13	Colorado Coal Co.	78	---	WS, WD, temp	TSP
Piceance Basin Co., see Figure 11a	Loma Coal Co.	78	---	WS, WD, temp	TSP
Hayden, CO see Figure 13	Sun Coal Co.	78	---	WS, WD, temp	TSP
C-b see Figure 11a	EPA	78	---	Upper air data	---
Craig, CO see Figure 13	EPA	78	---	Upper air data	---
Western Colorado	NOAA Boulder, CO	78	1 day	---	Airborne measurements of particles.
Western Colorado	National Fire Weather Library, U.S. Forest Service	78	---	1 pm local time records WS, WD, temp, precip, RH, lightning activity	---
Vernal, Utah see Figure 13	State of Utah	78	---	---	SO_2, NO_2, TSP
Deserado Mine near Rangely, CO	Deseret Generation and transmission coop.	78	---	WS, WD, temp	TSP
Rifle, CO see Figure 14	Empire Energy	78	---	WS, WD, temp	TSP
Montrose County, CO see Figure 3	Union Carbide	78	---	---	TSP

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Rock Springs, WY see Figure 13	EPA	78	---	Upper air data	---
U-a and U-b see Figure 10b	EPA	78	---	Upper air data	---
Hanksville, Utah see Figure 13	EPA	78	---	Upper air data	---
Cedar Mountain, Utah	U.S. BLM	78	---	WS, WD, temp	---
Midway Between C-b and Gunnison	Amax	78	---	WS, WD, temp, precip	---
White River: U-a, U-b see Figure 10b	White River Shale Oil Corporation	78, 79	2 years of baseline data and 6 meterological towers still operating	Baseline S1. W10 S2. W10, W20, W30, T10, T30, RH, σ_θ σ_w S3. W10 S4. W10, T10, σ_θ σ_w S5. W10 S6. W10, W20, W30, T10, T30, RH, σ_θ, σ_w, P, NR, AR, RW S7. W10 S8. W10 S9. W10, T10 S10. W10, T10 S11. W10, T10 S12. W10, T10 S13. W10, T10 NOTE: S2, S4, S6, S10, S11, S13 are still operating	Baseline S1 SO_2, H_2S, TSP S2 SO_2, CO, NO_2, TM, H_2S, HC, COH, TSP, O_3, LVR S3 SO_2, CO, NO_2, H_2S, HC, TSP, O_3 S4 SO_2, H_2S, TSP S5 SO_2, H_2S, TSP S6 SO_2, CO, NO_2, H_2S, HC, TSP, O_3 S7 SO_2, H_2S, TSP S8 SO_2, H_2S, TSP S9 VIS NOTE: Some air quality measurements are still being made
White River: Ua and Ub	White River Shale Oil Corporation	80	5 years	---	5 years of O_3 data Long-term ozone variability is governed by the movement of fronts over the sites and the intrusion of stratospheric ozone

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
C-a Rio Blanco see Figure 11a	Rio Blanco Oil Shale Company	78, 81	Baseline 2/75 to 1/77 Continuous (current)	Baseline S1 W10, W30, W60, T10, T30, T60, temp diff, precip, P, SR, RH, snow S2 W10, T10, precip, snow S3 W10, T10, precip, snow S4 W10, T10, precip, snow Current S1 W10, W60, T10, temp diff, precip, P, SR, dew point at 10m, snow S2 W10, T10, precip, snow S3 W10, T10, precip, snow S7 W10, T10, precip, snow	Baseline S1 SO_2, H_2S, NO, NO_x, CO, O_3, CH_4, THC, TSP S2 SO_2, H_2S, CH_4, THC, TSP S3 SO_2, H_2S, NO, NO_x, CO, O_3, CH_4, THC, TSP S4 SO_2, H_2S, CH_4, THC, TSP Current S1 SO_2, H_2S, NO, NO_x, CO, O_3, TSP S3 SO_2, H_2S, NO, NO_x, CO, O_3, TSP S2 TSP S7 SO_2, H_2S, NO, NO_x, CO, O_3, TSP S8 TSP S9 TSP Also visibility and toxicology studies
C-a Rio Blanco see Figure 11a	Rio Blanco Oil Shale Company	82, 83, 84	Baseline 2/75 to 1/77 Other 12/77 to 11/78 12/78 to 11/79	Baseline S1, S2, S3, S4; same as [81] Other S1, S2, S3 same as [81]	Baseline S1, S2, S3, S4; same as [81] Other S1, S2, S3 same as [81] S5 SO_2 S6 TSP
C-a Rio Blanco	Rio Blanco Oil Shale Company	85	Baseline	---	Analyzed the diurnal differences in O_3 concentrations in the valleys and on the hillsides
C-b Shale Oil Project see Figure 11a	Occidental Oil Shale, Inc.	85	Ditto	---	Ditto

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
C-a Rio Blanco	Rio Blanco Oil Shale Company	86	10/1/74 to 10/15/74	Vertical temperature structure from near the surface to 13,000 ft MSL---times per day 05:00, 08:00, 12:00, 17:00---aircraft soundings some wind data by pilot balloon	---
C-a Rio Blanco	Rio Blanco Oil Shale Company	87	1/20/75 to 2/9/75	Vertical temperature structure by aircraft. Times--05:00, 08:00, 11:00, 17:00---some wind data by pilot balloons	---
C-a Rio Blanco	Rio Blanco Oil Shale Company	88	4/14/75 to 5/1/75	Ditto	---
C-a Rio Blanco	Rio Blanco Oil Shale Company	89	7/12/75 to 7/26/75	Ditto	---
C-a Rio Blanco	Rio Blanco Oil Shale Company	90, 91	10/17/76 to 10/28/76	A tracer gas (SF_6) study and analysis. Gas released near the NW corner of C-a---WS, WD, temp, from 60m tower---Pibal data	---
C-a Rio Blanco	U.S. DOE and EPA	92, 93	August 1980	33 Airsonde ascents, aircraft soundings of temperature and wind, ground radiation measurements	Aircraft soundings of O_3, particle size distribution, and ionic analysis of airborne particles
C-a Rio Blanco	U.S. DOE and EPA	94, 95	August 1980	Electronic weather stations, tethersonde data, acoustic sonder data, pibal-minisonde data, tracer data in Corral Gulch	---

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
C-a Rio Blanco	U.S. DOE	96	August 1980	Nightime drainage and daytime dual-tracer experiments in Corral Gulch	---
C-a Rio Blanco	U.S. DOE	97	July 1981	Individual-tracer experiments along ridge tops above Corral Gulch	---
C-b Shale Oil Project	Occidental Oil Shale, Inc.	98, 99, 100 101, 114	Baseline 11/74 to 10/76 Other 1978 and 1979	Baseline S20 W10, AR, RH, temp, precip S21 W10, AR, RH, temp, precip S22 W10, RH, temp, precip S23 W10, W30, W60, T10, T60, temp diff, σ_w, σ_θ, AR, RH, precip, P, SR S24 W10, T10, RH, precip, P S31 W10, T10 S32 W10, T10 S33 W10, T10 S41 W10, T10 S42 W10, T10 S43 W10, T10 S44 W10, T10 Other Data from most of the stations, some stations shut down, some measurements discontinued S45 W10, T10 S46 S10, T10	Baseline S20 SO_2, H_2S, TSP, THC, CH_4, O_3, NO_x, NO, CO S21 SO_2, H_2S, TSP S22 SO_2 H_2S, TSP S23 SO_2, H_2S, TSP, THC, CH_4, O_3, NO_x, NO, CO S24 SO_2, H_2S, TSP Also, visibility studies, see Figure 19. Also, trace element analyses. Other Data from most of the stations, some stations shut down, some measurements discontinued S42 TSP S56 TSP

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
C-b Shale-Oil Project	Occidental Oil Shale, Inc.	102, 103	September 1978	Meteorological measurements at S20, S22, S23, S24, S42, S45, S46, S56; tethersonde data; SF_6 tracer studies throughout the diurnal cycle, releases at 100m to 150m above the ground	---
C-b Shale Oil	Occidental Oil Shale, Inc.	104	Same as [86]	Same as [86] except over C-b	---
C-b Shale Oil	Occidental Oil Shale, Inc.	105	Same as [87]	Same as [87] except over C-b	---
C-b Shale Oil	Occidental Oil Shale, Inc.	106	Same as [88]	Same as [88] except over C-b	---
C-b Shale Oil	Occidental Oil Shale, Inc.	107	Same as [89]	Same as [89] except over C-b	---
C-a and C-b	Rio Blanco and Occidental	108	Same as [86, 104]	Upper air correlation studies for the fall---between C-a, C-b, and Grand Junction	---
C-a and C-b	Rio Blanco and Occidental	109	Same as [87, 105]	Same as [108], except for the winter	---
C-a and C-b	Rio Blanco and Occidental	110	Same as [88, 106]	Same as [108], except for the spring	---
C-a and C-b	Rio Blanco and Occidental	111	Same as [89, 107]	Same as [108], except for the summer	---
C-a and C-b	Rio Blanco and Occidental	112, 113	1974/1975 upper air data [108 to 111]; some earlier data	Synthesis of data collected over C-a/C-b by EG&G---main emphasis on the upper air data of 1974/1975	---

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
C-a, C-b, U-a U-b	U.S. DOE sponsored the analysis	115, 116, 117	Baseline data: 2/75 to 10/76	Analysis of the federal lease tract Baseline data for: WS, WD, σ_θ, lapse rates, RH, temp	Analysis of the federal lease Baseline data for: TSP, O_3
Salt Lake Valley	Deseret test center and NOAA, Utah	118	January 1971	Coupling of upper layer flows with winds in an urban-mountain-valley situation	---
Eastern Utah and Western Colorado	---	119, 122	Up to 1977	Survey of several transport and diffusion studies in Western Colorado and Eastern Utah	---
Project Rulison near Grand Junction, CO	U.S. Atomic Energy Commission	120	June 1970	Comparison of atmospheric stability between a valley and a mountain site	---
Various Valley Sites East and North of Colorado Oil Shale Area	Colorado State University	121	Various periods from 12/75 to 10/78	Used airsondes, tethersondes, and acoustic radar to study the evolution of temperature inversions in valleys over all seasons of the year	---
Oklahoma	NOAA	123	Summer 1980	Proved the feasibility of long-range tracer experiments. Applicable to the oil shale area	---
Utah and Colorado	NOAA, U.S. DOE, U.S. BLM, States of Colorado and Utah	4, 124, 125 126, 127	Historical Meterological and Climatic Data	Locations of stations and usual upper air and surface meterological data	---

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Upper Colorado Basin	Colorado State University	128, 129 130	Historical precipitation and surface temperature data	Relationships between precipitation and surface temperature data, and the terrain elevation, slope, and orientation to the sun	---
Hayden Power Plant	Colorado State University	131	December 1979	Indium tracer study in the Yampa Valley between Steamboat Springs and Craig, Colorado	---
Cool Creek and Alkali Creek Valleys	Climax Molybdenum Company	132	August 1979	SF_6 tracer studies in two creek valleys near Crested Butte, CO	---
Northwestern Colorado	U.S. Forest Service	133	---	Modeling study over northwestern Colorado	---
Hayden and Craig Power Plans	Colorado-Ute Electric Association	134	Since 1971	Study of wind patterns around the two power plant sites	---
Gunnison Valley, Colorado	Colorado State University	135	February 1979	Shape of winter time air temperature inversions within a mountain valley	---
South Park, Colorado	Colorado State University	136	July and August 1977	Daytime wind systems in South Park Basin vs surface based heating	---
Various Colorado Valleys East and North of the Oil Shale Area	Colorado State University	137	Whiteman's data see [121]	Simulation of the daytime evolution of wind and temperature fields in narrow mountain valleys	---
Western Colorado	---	138	1979/1980 winter snow season	Snowfall forecasting in the Colorado Mountains	---

TABLE 9. (contd)

Location (Oil Shale Tract)	Monitoring Organization	References	Period of Measurement	Meteorological Parameters	Air Quality Parameters
Rocky Mountain West	U.S. EPA	139	Current to 1981	---	Current and future visibility and particle monitoring in the west and over the Piceance Basin
Uintah Basin, Utah	U.S. BLM	140	Current to 1981	Status and planning for synfuel development	Status and planning for synfuel development

the monitoring organization (usually the sponsoring company), the references used in our analysis, the period of measurement (usually the period covered in the cited reference), and the meteorological and air quality parameters measured or studied in the cited reference.

To aid in locating the meteorological and air quality stations in and around tracts U-a, U-b, C-a and C-b, we have included Figures 16, 17, 18 and 19:

- U-a and U-b stations are given in Figure 16.
- C-a stations are given in Figure 17.
- C-b stations are given in Figure 18.
- Visibility station between C-a and C-b is shown in Figure 19.

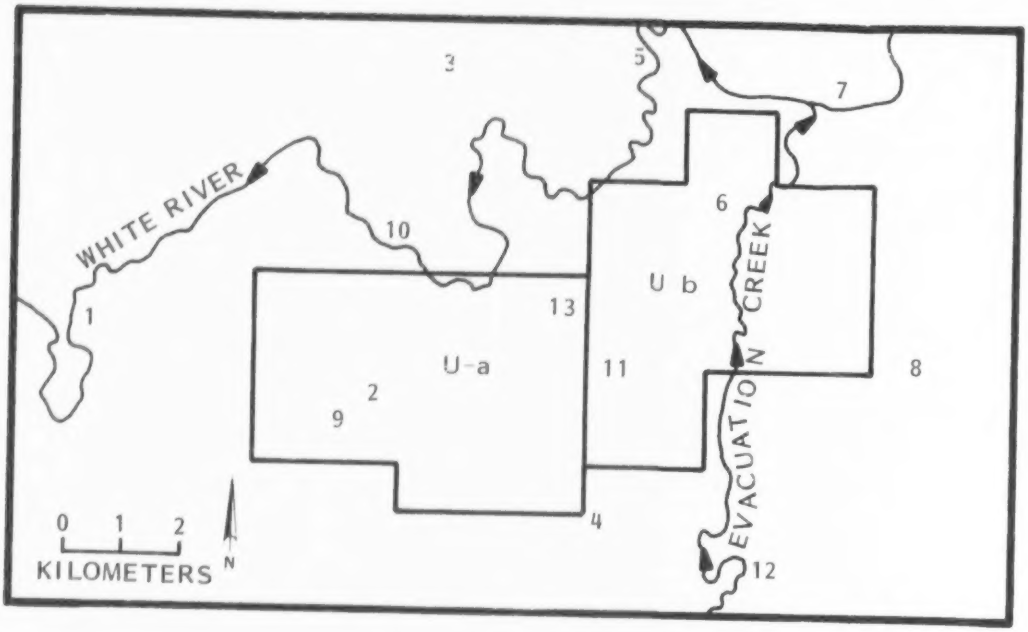
In addition, Figures 20 to 23 give the meteorological stations archived at NCC (National Climatic Center, Asheville, NC) in and around the mesoscale domain defined in Figure 2.

EVALUATION OF METEOROLOGICAL AND AIR QUALITY DATA

The local and mesoscale analyses of the dispersion and fate of airborne pollutants over the Utah/Colorado oil shale area must address a unique set of features: the specific emissions from the proposed oil shale facilities, the complex terrain in this part of Utah and Colorado, the unique characteristics of the region's atmospheric chemistry, and the region's nontrivial features producing wet and dry removal of pollutants. The references cited in the previous subsection consider several of these features and an adequate synthesis of these information and data sources would go far in determining the air pollution carrying capacity of the oil shale area. However, such a synthesis has not been completed. Even if it were, there would still be areas of investigation that would be required. The following paragraphs outline some of the results that have been obtained and some of the areas requiring further investigation.

Interactive Wind Systems

The air quality issues for the oil shale area that must be addressed and the interactions between the complex terrain and the solar-dominated atmosphere impose a wide spectrum of time and space scales on the components of a meteorology module of an air quality model (AQM). The scales of motion that must be considered in such a module range from small-scale turbulent eddies, to slope flows, to mountain-valley and basin flows, and on to the synoptic conditions producing upper-level gradient flows over the Rocky Mountains. Due to diurnal and seasonal variations in solar and terrestial radiation balances, these flow fields will be highly interactive at certain times, while at other times the system will essentially be uncoupled. In addition, these flow systems will be modified through their interaction with the atmospheric moisture field, and non-precipitating and precipitating


3
5
7
WHITE RIVER
10
6
U b
CREEK
13
1
U-a
11
N
8
2
9
EVACUATION
4
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KILOMETERS
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12

Figure 16. The meteorological and air quality stations in and around Federal Oil Shale Tracts U-a & U-b.

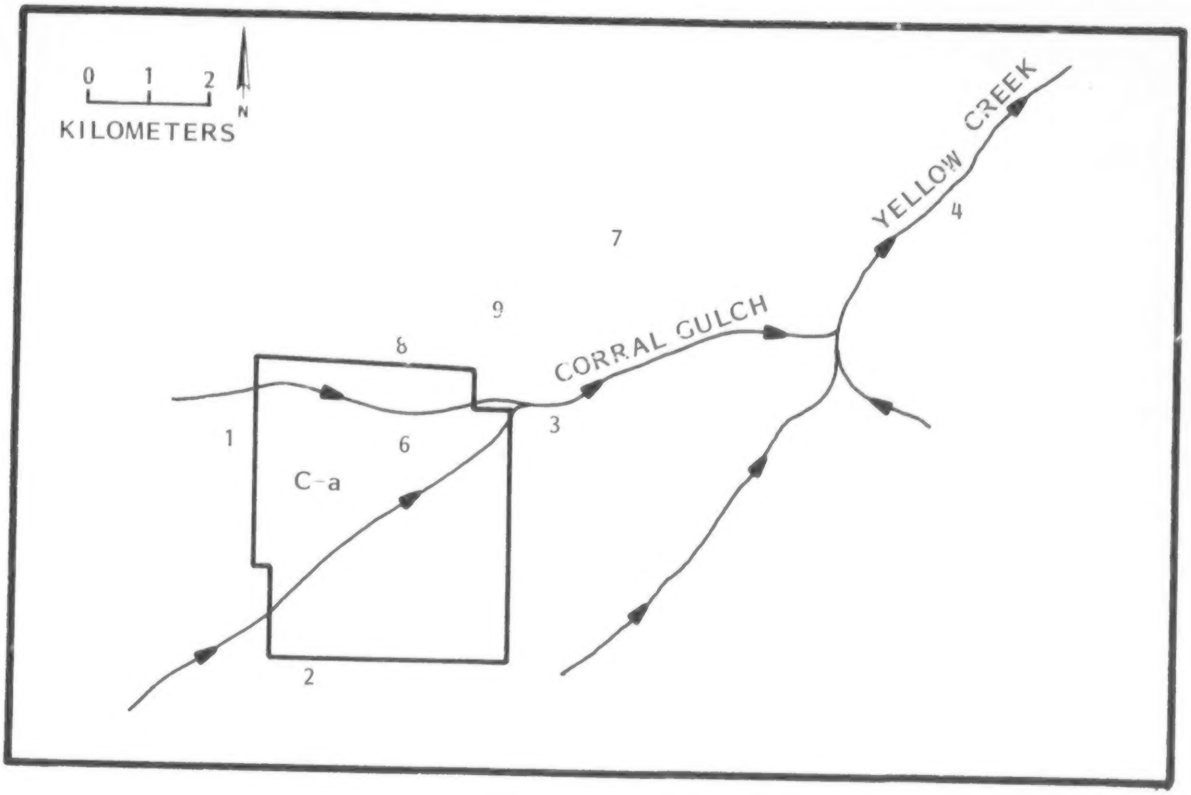
0
1
2
KILOMETERS
N
YELLOW CREEK
4
7
9
CORRAL GULCH
8
1
6
3
C-a
2

Figure 17. The meteorological and air quality stations in and around Federal Oil Shale Tract C-a.

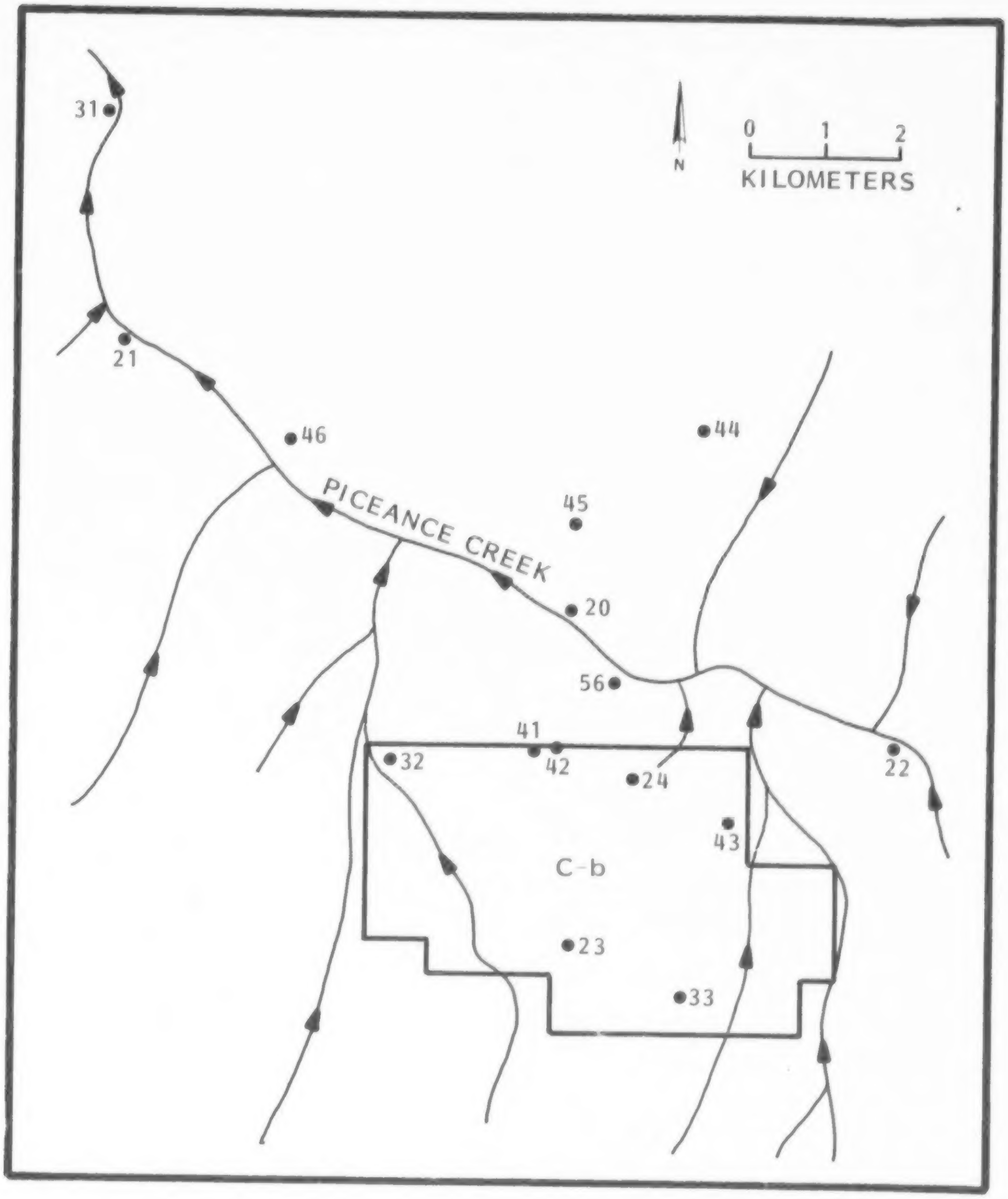
31
N
0
1
2
KILOMETERS
21
46
44
PICEANCE CREEK
45
20
56
41
42
32
24
22
43
C-b
23
33

Figure 18. The meteorological and air quality stations in and around Federal Oil Shale Tract C-b.

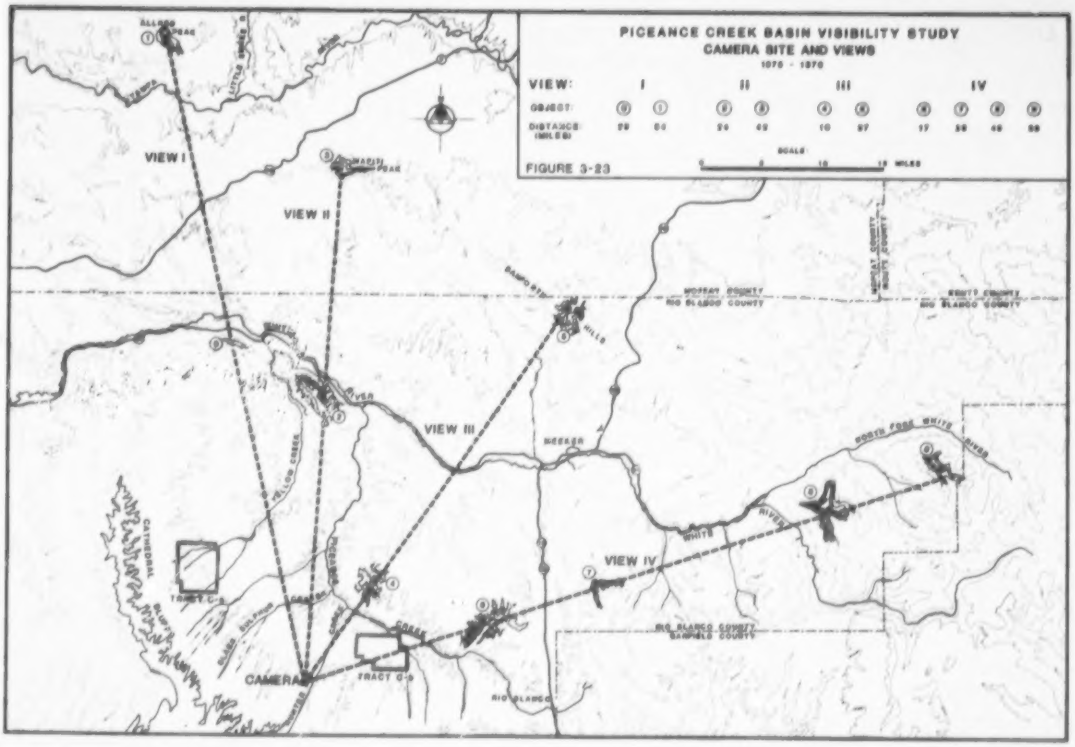
PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
VIEW:
I
II
III
IV
OBJECT:
DISTANCE (MILES)
SCALE
MILES
FIGURE 3-23
VIEW I
VIEW II
VIEW III
VIEW IV
CAMERA
PEAK
DANFORTH HILLS
MOFFAT COUNTY
RIO BLANCO COUNTY
ROUTT COUNTY
GARFIELD COUNTY
WHITE RIVER
NORTH FORK WHITE RIVER
MEEKER
RIO BLANCO
YELLOW CREEK
PICEANCE CREEK
CATHEDRAL BLUFFS
TRACT C-a
TRACT C-b

Figure 19. Piceance Creek Basin visibility study camera site and views [100].

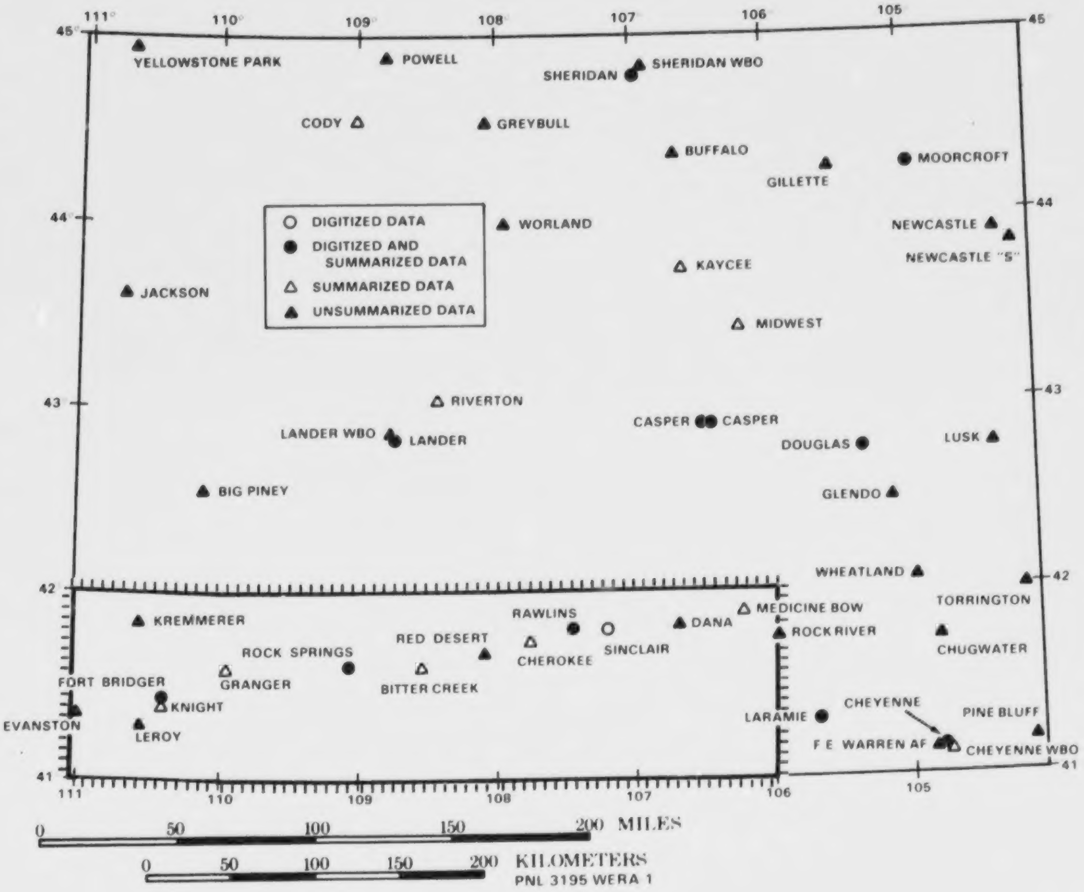
111°
110°
109°
108°
107°
106°
105°
45°
44°
43°
42°
41
YELLOWSTONE PARK
POWELL
SHERIDAN
SHERIDAN WBO
CODY
GREYBULL
BUFFALO
GILLETTE
MOORCROFT
DIGITIZED DATA
DIGITIZED AND SUMMARIZED DATA
SUMMARIZED DATA
UNSUMMARIZED DATA
WORLAND
NEWCASTLE
NEWCASTLE "S"
JACKSON
KAYCEE
MIDWEST
RIVERTON
LANDER WBO
LANDER
CASPER
CASPER
DOUGLAS
LUSK
BIG PINEY
GLENDO
WHEATLAND
TORRINGTON
KREMMERER
RAWLINS
DANA
MEDICINE BOW
ROCK RIVER
CHUGWATER
RED DESERT
ROCK SPRINGS
CHEROKEE
SINCLAIR
FORT BRIDGER
GRANGER
BITTER CREEK
KNIGHT
EVANSTON
LEROY
LARAMIE
CHEYENNE
PINE BLUFF
F E WARREN AF
CHEYENNE WBO
0 50 100 150 200 MILES
0 50 100 150 200 KILOMETERS
PNL 3195 WERA 1

Figure 20. NCC station locations in Wyoming, showing stations in Wyoming's portion of the mesoscale domain, [124].

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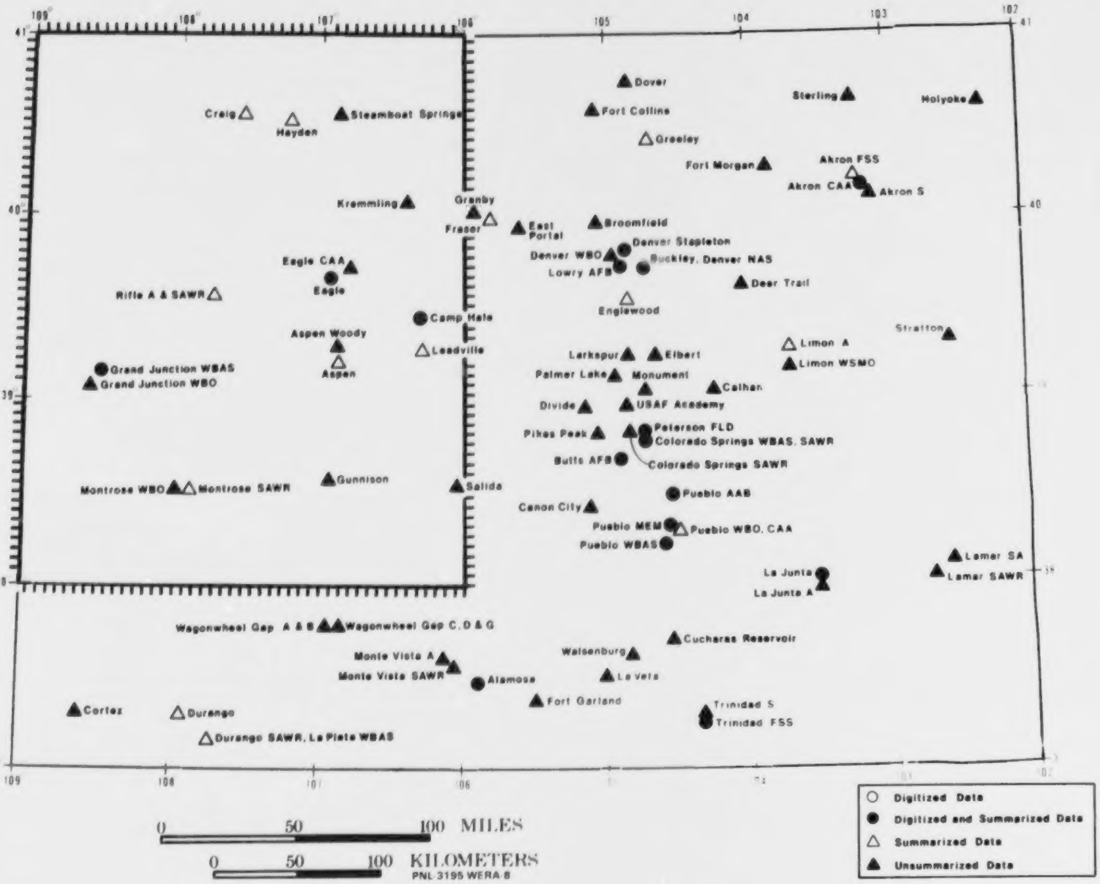
109°
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40
39
38
37
Dover
Sterling
Holyoke
Fort Collins
Craig
Hayden
Steamboat Springs
Greeley
Fort Morgan
Akron FSS
Akron CAA
Akron S
Kremmling
Granby
Fraser
East Portal
Broomfield
Denver Stapleton
Denver WBO
Buckley, Denver NAS
Lowry AFB
Eagle CAA
Eagle
Deer Trail
Rifle A & SAWR
Englewood
Camp Hale
Aspen Woody
Leadville
Stratton
Limon A
Limon WSMO
Grand Junction WBAS
Grand Junction WBO
Aspen
Larkspur
Elbert
Palmer Lake
Monument
Calhan
Divide
USAF Academy
Pikes Peak
Peterson FLD
Colorado Springs WBAS, SAWR
Butts AFB
Colorado Springs SAWR
Gunnison
Montrose WBO
Montrose SAWR
Salida
Pueblo AAB
Canon City
Pueblo MEM
Pueblo WBO, CAA
Pueblo WBAS
Lamar SA
Lamar SAWR
La Junta
La Junta A
Wagonwheel Gap A & B
Wagonwheel Gap C, D & G
Cucharas Reservoir
Walsenburg
Monte Vista A
Monte Vista SAWR
Alamosa
La Veta
Fort Garland
Trinidad S
Trinidad FSS
Cortez
Durango
Durango SAWR, La Plata WBAS
0
50
100
MILES
0
50
100
KILOMETERS
PNL 3195 WERA 8
○ Digitized Data
● Digitized and Summarized Data
△ Summarized Data
▲ Unsummarized Data

Figure 21. NCC station locations in Colorado, showing stations in Colorado's portion of the mesoscale domain, [4].

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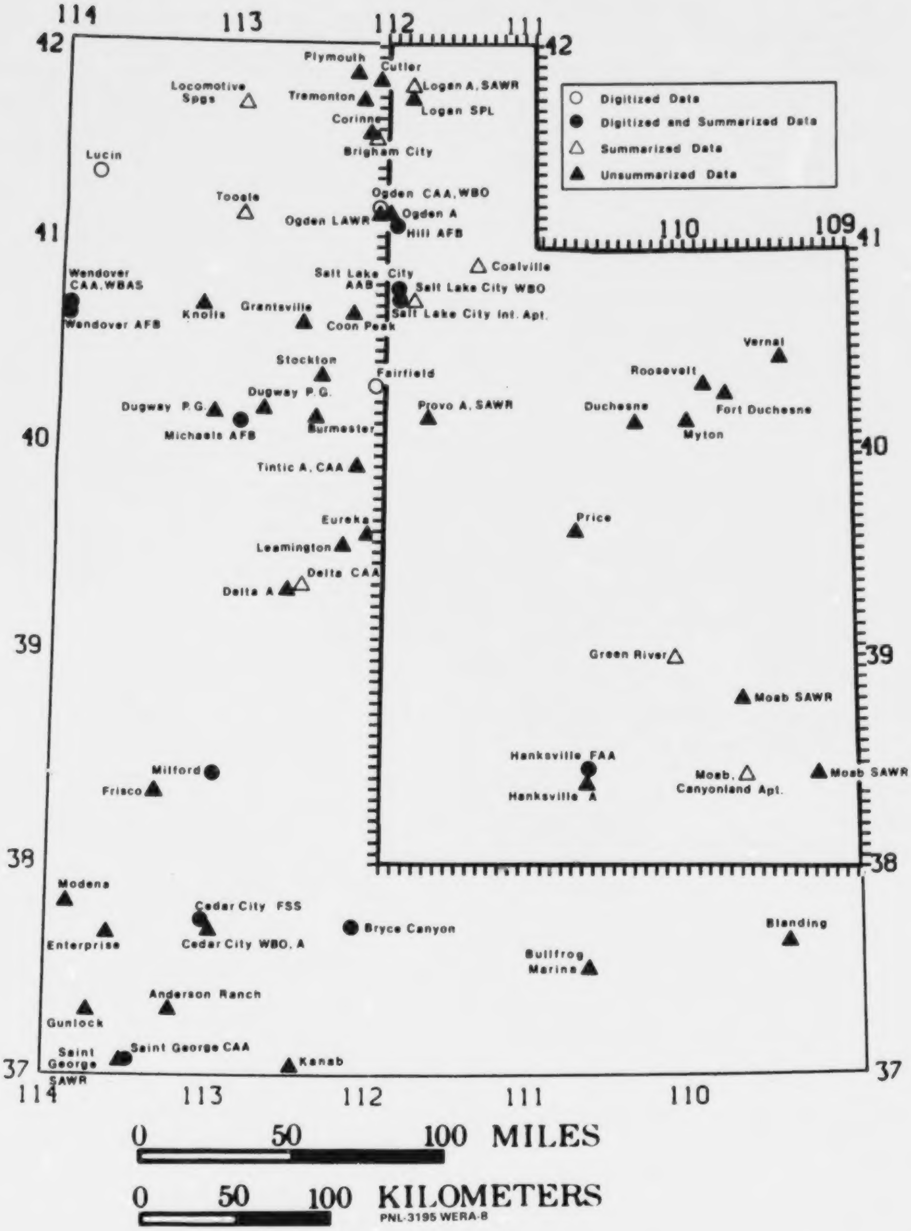
114
113
112
111
110
109
42
41
40
39
38
37
○ Digitized Data
● Digitized and Summarized Data
△ Summarized Data
▲ Unsummarized Data
Plymouth
Cutler
Locomotive Spgs
Tremonton
Logan A, SAWR
Logan SPL
Corinne
Brigham City
Lucin
Tooele
Ogden CAA, WBO
Ogden LAWR
Ogden A
Hill AFB
Coalville
Wendover CAA, WBAS
Wendover AFB
Knolls
Grantsville
Salt Lake City AAB
Salt Lake City WBO
Salt Lake City Int. Apt.
Coon Peak
Vernal
Stockton
Fairfield
Roosevelt
Fort Duchesne
Dugway P.G.
Dugway P.G.
Michaels AFB
Burmester
Provo A, SAWR
Duchesne
Myton
Tintic A, CAA
Price
Eureka
Leamington
Delta CAA
Delta A
Green River
Moab SAWR
Milford
Frisco
Hanksville FAA
Hanksville A
Moab, Canyonland Apt.
Moab SAWR
Modena
Cedar City FSS
Enterprise
Cedar City WBO, A
Bryce Canyon
Blanding
Bullfrog Marina
Anderson Ranch
Gunlock
Saint George CAA
Saint George SAWR
Kanab
0 50 100 MILES
0 50 100 KILOMETERS
PNL-3195 WERA-8

Figure 22. NCC station locations in Utah, showing stations in Utah's portion of the mesoscale domain, [4].

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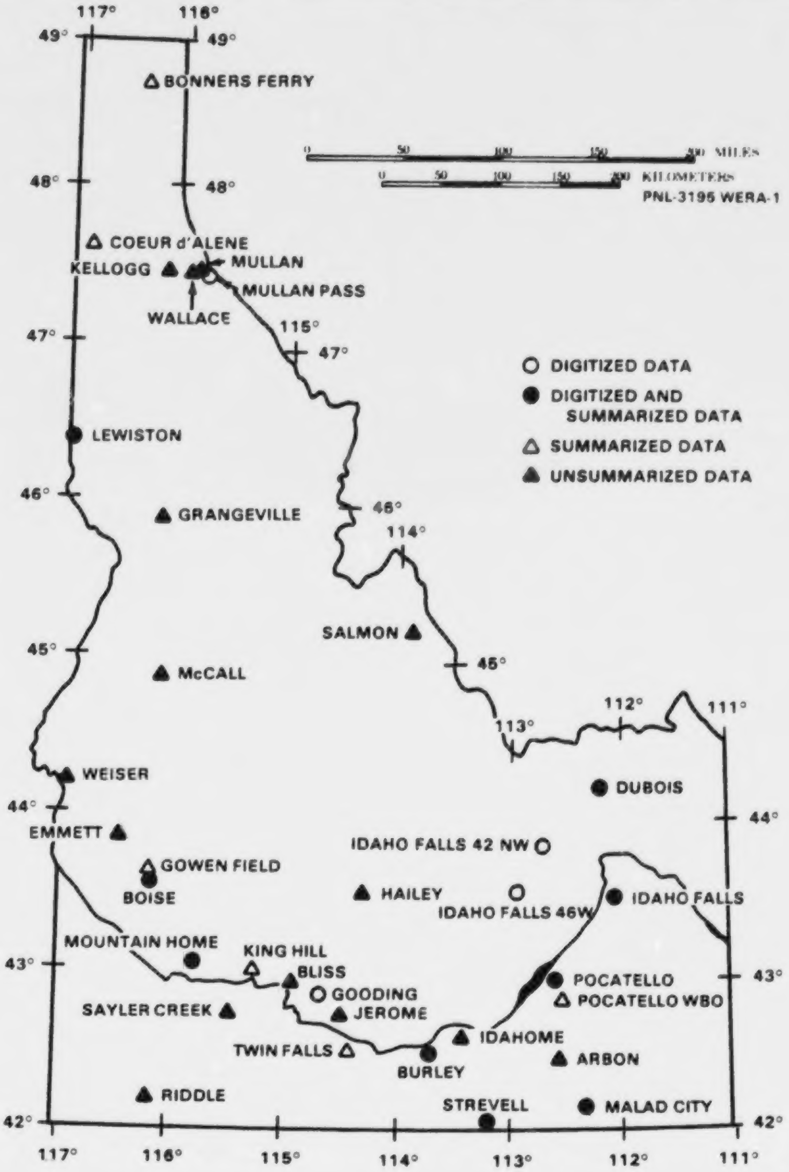
117°
116°
49°
49°
BONNERS FERRY
0 50 100 150 200 MILES
0 50 100 150 200 KILOMETERS
PNL-3195 WERA-1
48°
48°
COEUR d'ALENE
KELLOGG
MULLAN
MULLAN PASS
WALLACE
115°
47°
47°
○ DIGITIZED DATA
● DIGITIZED AND SUMMARIZED DATA
△ SUMMARIZED DATA
▲ UNSUMMARIZED DATA
LEWISTON
46°
46°
GRANGEVILLE
114°
SALMON
45°
45°
McCALL
112°
111°
113°
WEISER
DUBOIS
44°
44°
EMMETT
IDAHO FALLS 42 NW
GOWEN FIELD
BOISE
HAILEY
IDAHO FALLS 46W
IDAHO FALLS
MOUNTAIN HOME
KING HILL
BLISS
43°
43°
POCATELLO
GOODING
POCATELLO WBO
SAYLER CREEK
JEROME
IDAHOME
TWIN FALLS
BURLEY
ARBON
RIDDLE
STREVELL
MALAD CITY
42°
42°
117°
116°
115°
114°
113°
112°
111°

Figure 23. NCC station locations in Idaho, [124].

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cloud systems. Examples of interactive wind systems important to the oil shale area are shown in Figures 24 and 25.

Evidence of Interactive Wind Regimes from Tract Data

From their analysis of the baseline data from the federally leased oil shale tracts in Utah and Colorado, Wolf et al [45,46,47] concluded that "continuity of airflow" between the four tracts (U-a, U-b, C-a, C-b) exists during the afternoon during the warmer months when the gradient flow is sufficiently strong to dominate the region. At other times, local conditions dominate the surface air flow. Examples of local conditions that were identified by Wolf et al are:

- Midmorning heating of the ENE facing slope above tract C-a causes upslope winds for a short time before noon (this has the potential of severely impacting Cathedral Bluffs with pollutants from C-a, see Figure 14).

- Similar upslope flows from the White River valley are observed over tracts U-a and U-b.

- Drainage flows during nighttime are prominent on all four tracts. The drainage flow along the Piceance Creek adjacent to tract C-b is sufficiently deep throughout the year that the meteorological site 120m above the valley floor is dominated by this flow.

Other analyses of this tract data, additional data collected over the same tracts, and data sets collected over other tracts in the same general area [68 to 114] have arrived at similar conclusions. Other studies, however, tend to assign a higher frequency of dominance to the gradient winds over the area than did Wolf et al [115,116,117]. The general picture of the wind regimes over the Utah-Colorado oil shale area takes the following form:

- The gradient winds over the area can be reasonably approximated by the 700 mb to 500 mb winds over the Grand Junction NWS station.

- These gradient winds are predominantly from the SSW to WNW quadrant as measured at the 700 mb level over Grand Junction.

- An estimate of the regional mixing heights can be obtained from the NWS stations "surrounding" the mesoscale domain, see Figures 13 and 26.

- The gradient wind regime, when the gradient winds dominate, occurs during strong wind conditions (both night or day) and during the daytime with strong insolation. These conditions are conducive to high levels of mechanical and thermal turbulence which, in turn, cause strong vertical currents in the lower atmosphere and the downward transport of momentum. Near neutral stability conditions would be expected.

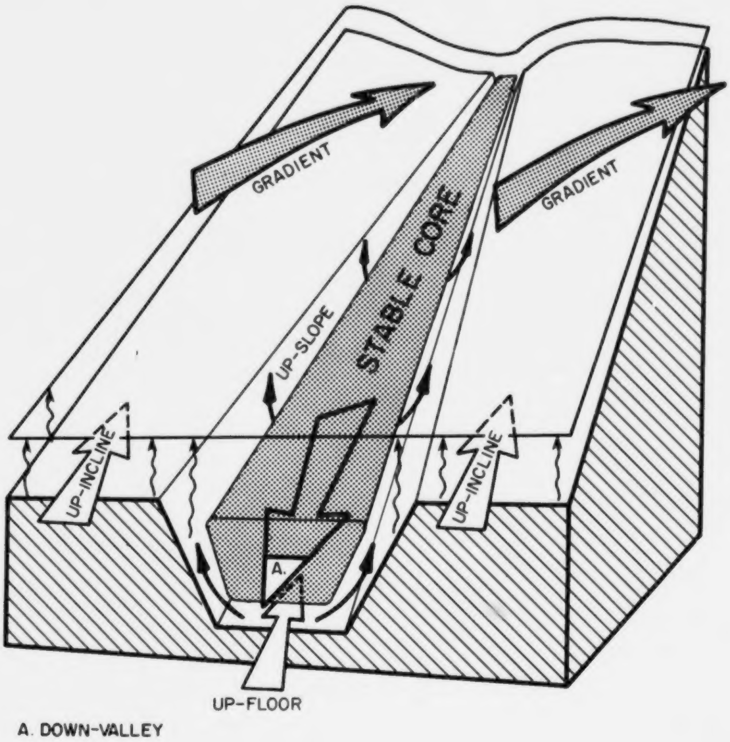
GRADIENT
GRADIENT
STABLE CORE
UP-SLOPE
UP-INCLINE
UP-INCLINE
A.
UP-FLOOR
A. DOWN-VALLEY

Figure 24. Interactive wind systems identified in field studies on the Western Slope of the Rocky Mountains [93,121]: typical mid-morning wind structure over and within a deep valley illustrating five interactive wind systems.

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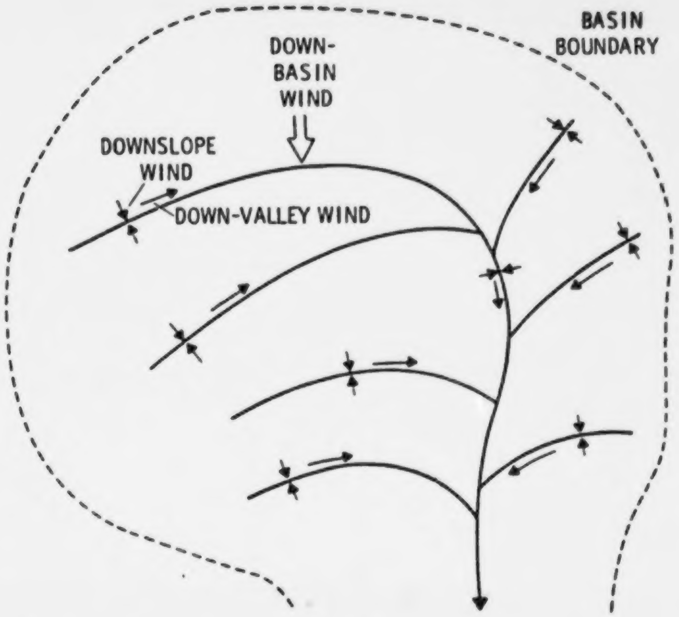
BASIN
BOUNDARY
DOWN-
BASIN
WIND
DOWNSLOPE
WIND
DOWN-VALLEY WIND

Figure 25. Interactive wind systems identified in field studies on the Western Slope of the Rocky Mountains [93]: superposition of three nocturnal drainage flows of different length scales, flows that are analogous to nighttime winds over the Yellow and Piceance Creek Watershed in Colorado.

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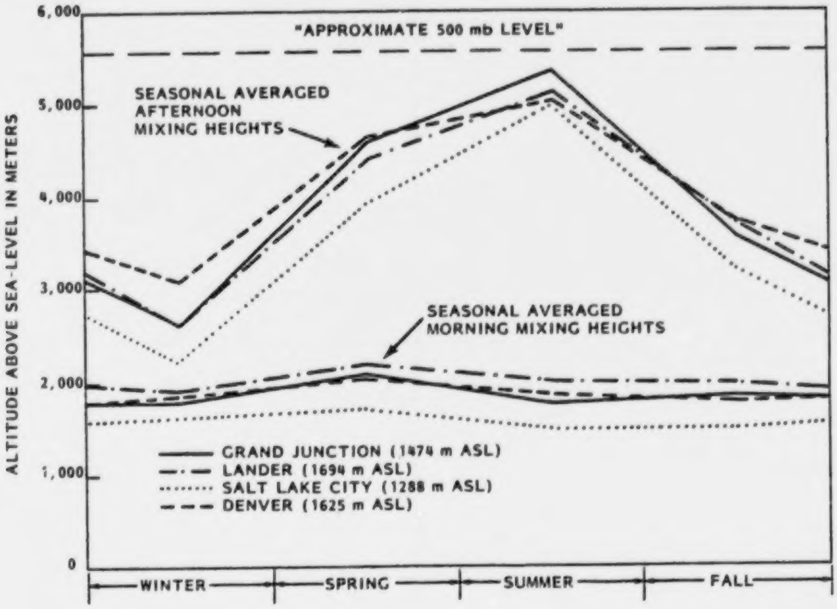

Figure 26. Seasonal averaged morning and afternoon mixing heights in the neighborhood of the Utah-Colorado oil shale areas, [141].

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- Down valley nocturnal wind regime occurs at night with lighter winds aloft and a strong surface-based radiation inversion. A very stable condition would be expected.

- Up valley wind regime occurs during the daytime with rather light winds aloft. Unstable conditions would be likely.

Like most meteorological generalizations, the above picture can be highly perturbed by local terrain, ground cover, and various other meteorological/terrain influences. For example, Barr and Clements [94,95] collected some very interesting and complex vertical wind soundings over tract C-a during a summertime, nocturnal drainage flow experiment. They found the classical low-level drainage flow over tract C-a in the first few hundred meters above the surface topped by a deep easterly wind regime which, in turn, was topped by gradient level winds analogous to those over Grand Junction. The depth of the easterly wind regime was from about 2300m (below the top of Cathedral Bluffs) to about 3800m (higher than Flat Tops, but lower than the peaks to the east of Flat Tops). The cause of this wind regime (which would transport pollutants from a high stack over C-a to the Cathedral Bluffs) is unknown. It may possibly be due to flow blockage by, or large scale drainage from, the Flat Tops or the higher peaks to the east.

These midlevel winds identified by Barr and Clements need to be understood if an adequate determination of pollutant transport over the oil shale area is to be obtained.

Diurnal Evolution of the Coupling-Decoupling of Valley and Upper-Level Winds

For the last several years, a group of Colorado State University investigators [121,137] have been studying the time evolution of inversions in western Colorado valleys (i.e., Yampa Valley near Steamboat Springs, North fork of the Gunnison Valley near Paonia, Eagle and Gore Valleys near Vail, South Fork of the White River near Meeker, and Roaring Fork Valley near Aspen). From these studies, a four phase, valley atmospheric structure emerges: the evening transition phase, the nighttime phase, the morning transition phase, and the daytime phase. Although mountain valleys differ in size, shape, orientation and other topographical characteristics, their meteorology is similar. These similarities are summarized below in chronological order [142]:

- Local circulations begin to form an hour or two before sunset.

- The valley atmosphere becomes decoupled from the upper air.

- Temperature inversions increase in depth, and winds within the inversion blow down the valley parallel to the valley axis.

- Wind speeds vary from valley to valley.

- The temperature inversions and down-valley flows increase rapidly in depth.

- Several hours after sunset the inversions and down-valley flows have attained nearly the full depth of the valleys.

- Conditions approach a near-steady state after this time, lasting until sunrise.

- After sunrise meteorological conditions are favorable for fumigations on the valley floor and sidewalls as boundary layers grow upwards from the surfaces and as the stable core sinks.

- After the inversions are destroyed, the atmosphere becomes coupled with the circulations aloft. This condition lasts until one or two hours before sunset and should be amenable to modeling with a mass-consistent flow model operating on terrain of the desirable scale.

- During the nighttime and morning transition phases, vertical wind and temperature structure evolution is quite similar from night to night for undisturbed clear weather conditions.

An example of the characteristic structural changes associated with each of the four phases of valley meteorology, along with the timing of the phases, is illustrated in Figure 27a. In addition, Figure 27b indicates the ideal region where the upper-level flow (the mesoscale flow field) will dominate, including the region where this flow may be coupled to the surface flows. In interpreting these diagrams for the oil shale areas, one should be cautious because valleys do differ in topography, the rate of inversion buildup, down valley wind speeds, depth of inversion at sunrise, mean potential temperature gradient at sunrise, and method and time of inversion destruction.

Other information that is required to better understand the coupling-decoupling problems over the Piceance Basin consists of:

- Diurnal evolution of atmospheric structures over landforms other than deep valleys.

- Interactions of wind systems of various scales, such as the drainage flows over the Yellow-Piceance Watersheds, see Figure 25.

- Multi-valley and basin-wide temperature inversions and the occurrence of stagnation zones.

- Topographical factors affecting mixed layer development over the entire region (see the next subsection).

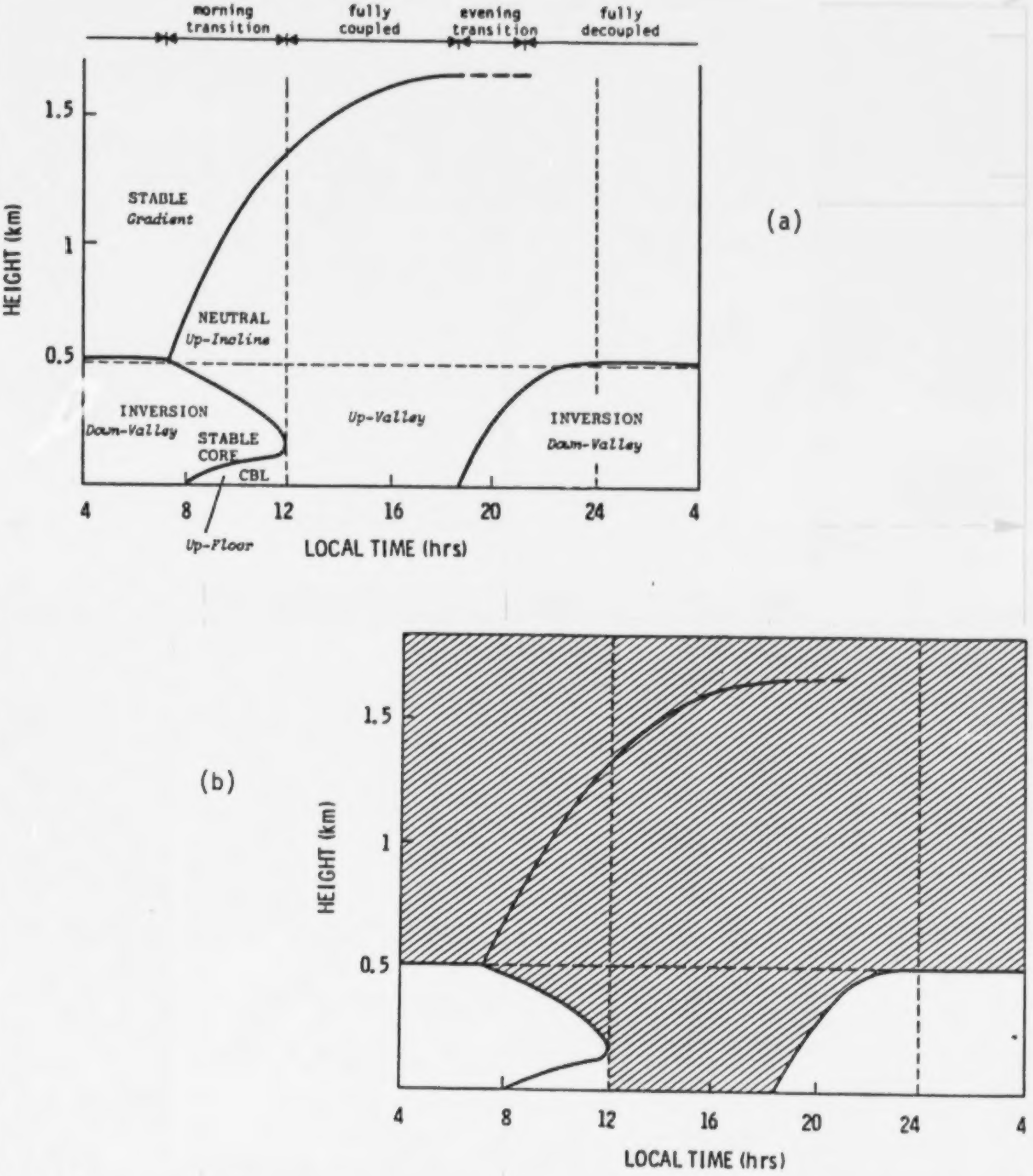


Figure 27. A schematic of the diurnal variation of the coupling-decoupling of valley and upper-layer flows over the oil shale areas, a summertime scenario [121,142]: (a) diurnal phases in temperature and wind structure (italics) in a 500 m deep valley, (b) mixed-layer height domain (shaded) of coupled flows (local and mesoscale flows).

Development of the CBL over the Western Slope of the Rockies

There are at least three pollutant-carrying layers over the western slope of the Colorado Rockies that evolve in time and space (see Figure 28): valley inversions at the bottom, a convective boundary layer (CBL) with its bottom at the top of the valley inversions, and above the convective layer, the free atmosphere where the gradient wind blows. Winds within the CBL typically blow up the western slope of the Rockies toward the Continental Divide.

Even though we know that the CBL is very important for transporting pollutants from the oil shale area to the east, there are still many questions that must be answered before we can quantify its impact [92,142]:

- What is the relationship between the winds in the CBL and the upper level winds?
- What is the diurnal and seasonal evolution of the CBL?
- How does the CBL depend on the underlying terrain and the radiative characteristics of the area?
- How does the depth of the CBL vary as the higher elevations on the western slope are approached?
- What is the process of decoupling the valley circulations from the flow aloft in the late afternoon?
- How do cloud cover and snow cover affect the evolution of the CBL?
- How do the Grand Junction and Salt Lake City NWS stations correlate with the growth and decay of the CBL?
- How does the diurnal evolution of the CBL affect the dispersal of pollutants leaving the oil shale area?
- How does enhanced convection over favored topographical landforms affect the CBL structure and its ability to transport pollutants?

Long-Range Atmospheric Impacts of the Oil Shale Area

In general, it is felt that the only major long-range impacts of the oil shale area will be in the areas of acid precipitation and/or regional visibility. Wolf [115] briefly examined these possibilities by means of an EPA trajectory model and the NWS rawinsonde network data for 1975-1976. The EPA computed trajectories for air parcels passing over the Utah-Colorado oil shale tracts at 6-hour intervals for the periods June and December 1975. Transport layers for June and December were between 200 and 3000m,

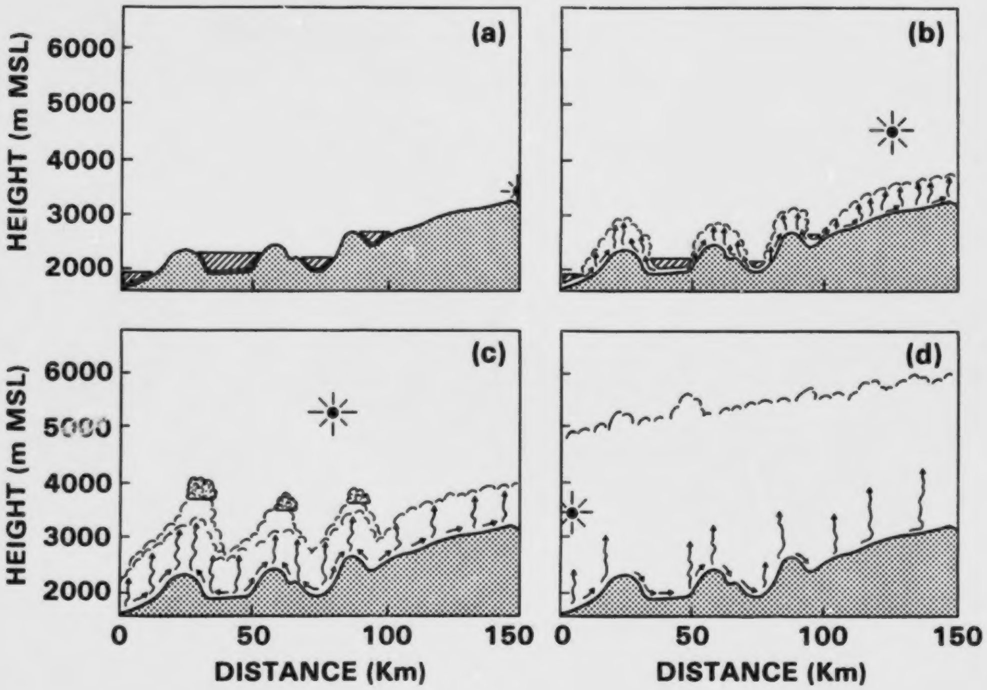

(a)
(b)
(c)
(d)
HEIGHT (m MSL)
6000
5000
4000
3000
2000
0
50
100
150
DISTANCE (Km)

Figure 28. The growth of the CBL over the Western Slope of the Rockies on a typical summer day [92,142].

and 200 and 600m, respectively. Because of the coarse grid used in the computation, the Utah-Colorado tracts were assumed to be at the same location, see Figure 29.

Figure 29 shows the results of these calculations for 48 hours and 96 hours of transport for both summer and winter. From these diagrams, it is apparent that the pollutants released from the oil shale region would be well dispersed for both seasons. In neither case is there appreciable transport to the west (less than a 2% frequency over Salt Lake City in the winter), while Denver lies within or very near the 8% impact frequency area in summer and winter. Observations that can be made from these diagrams are:

- A wide area of the Rocky Mountain west could be impacted by a large Utah-Colorado oil shale industry, especially in the areas of acid precipitation and regional visibility.

- To quantify results from such passive tracer calculations requires knowledge of the type and quantity of oil shale emissions being injected into the transport layers.

- Further information is also required on removal and transformation rates of pollutants as the acid and visibility chemical precursors are transported along the trajectories indicated in Figure 29.

- In general, the long-range transport of oil shale pollutants requires much additional investigation.

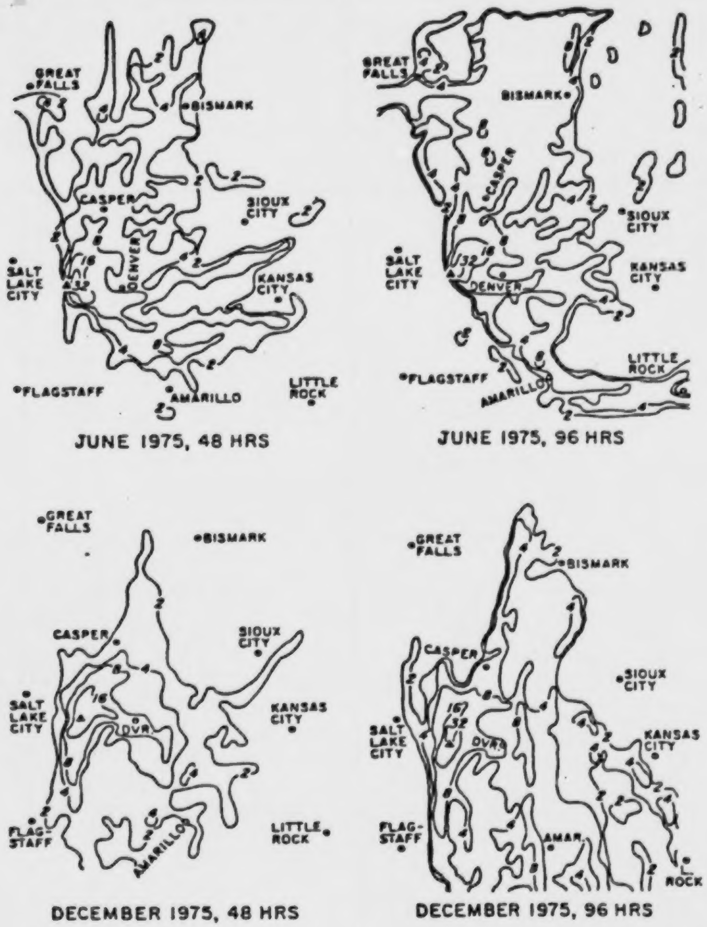
Chemistry Results and Needs

The chemistry module of an AQM addresses homogeneous and heterogeneous thermochemical and photochemical reactions, gas-to-particle conversions, and aerosol chemistry. Since these transformations occur on very small space scales, there is a commonality between the oil shale chemistry modules and chemistry modules used in other parts of the country. The possible differences that may occur will be based on the uniqueness of the emissions from oil shale facilities, the relatively low background levels of pollutants (except for dust, ozone, and possibly some hydrocarbons), the high-altitude, and the large number of sunny days with low absolute and relative humidities.

Some areas that probably require more work so that oil shale AQM's can be improved are:

- Determination of photolysis rates, quantum yields and reaction rates for those oil shale emission species thought to be photochemically significant.

- Determination of whether or not amines, mercaptans and heterocyclic aromatics will be emitted in photochemically significant quantities from oil shale facilities.



GREAT FALLS
BISMARK
CASPER
SIOUX CITY
SALT LAKE CITY
DENVER
KANSAS CITY
FLAGSTAFF
AMARILLO
LITTLE ROCK
DVR
AMAR
ROCK

JUNE 1975, 48 HRS

JUNE 1975, 96 HRS

DECEMBER 1975, 48 HRS

DECEMBER 1975, 96 HRS

Figure 29. Percent frequency of trajectory traverses by air masses originating over the Utah-Colorado oil shale tracts (indicated by ▲) [115].

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- Evaluation of the thermochemical and photochemical effects of the conditions unique to the oil shale region, such as the high elevation enhanced ultraviolet flux, and the generally low prevailing humidity.

- Improvement of our knowledge of SO_2 oxidation, and the oxidation and transformation of NO_x and other nitrogen - containing compounds over the oil shale area.

- Study of the time evolution of the partitioning of volatile oil shale emissions, such as the determination of the percentage of As, Hg and Se in the condensed phase and in the vapor phase.

- Determination of the kinetics of homogeneous gas-to-particle conversion, especially for SO_2 to sulfates, NO_x to nitrates, and volatile hydrocarbons to non-volatile organics.

- Evaluation of the roles of coagulation, gas-to-particle conversion, diffusion and removal on the aerosol size distribution for oil shale related primary and secondary particles.

- Determination of the role of trace metals as airborne catalysts of gaseous emissions from oil shale.

- Consideration of the impact of foggy valleys on atmospheric chemical processes.

Wet and Dry Removal Results and Needs

The removal module of an AQM for the oil shale area considers the manner in which pollutants are removed from the air by wet and dry processes. As with the chemistry module, the processes of wet and dry removal are quite common from one part of the country to another part, as long as the standards of comparison are based on common ground cover, background pollutant levels, storm type and intensity, and topographical features. However, it is just these features that cause us to consider removal mechanisms over the Utah-Colorado area in a non-trivial manner.

Oil shale removal modules on the mesoscale and regional scale must consider the complexity of ground cover (i.e., sagebrush, juniper-pinyon forests, rocky soil, tall evergreen forests, and snow-covered plateaus), the blocking and wake effects of cliffs, valleys, hills and mountains, and the potential of the various storm systems to transport acid-precursor oil shale pollutants to sensitive lakes and soils (i.e., to the sensitive lakes on Flat Tops).

Some areas that probably require more work so that oil shale AQM's can be improved are:

- Elucidate individual mechanisms contributing to net deposition (wet and dry) of oil shale pollutants to various surfaces (forests, snow and ice fields, water and grasslands), using laboratory, chamber and wind tunnel studies.

- Determine dry removal rates as a function of the diurnal cycle and season of the year. Determine rate enhancement due to flow blockage and wake formation.

- Investigate the various routes through which NO and NO_2 may travel to ultimately arrive at the ground as nitrate in precipitation.

- Classify washout ratios for aerosols by storm type, location, season, rainfall rate, particle size, and mass median diameter.

- Elucidate SO_2 reaction rates and paths in aqueous solutions, giving reaction rates as functions of temperature and species concentration (such as, SO_2, O_3, H_2O_2, H^+, trace metals, organics and carbonaceous materials).

- Investigate the chemical conversion of pollutants in nonprecipitating clouds, and the conversion in and deposition by dew and frost.

- Define the mechanisms affecting the presence of NH_3 in precipitation.

- Determine how the acidity of precipitation is influenced by catalysts, neutralizing materials and other substances released by man-made facilities over the oil shale area.

- Determine the relative effect of nitric acid versus sulfuric acid concentrated in the snow pack over a winter season on fish populations during a spring thaw. (The conclusions of such a study are of great concern to evaluating the potential impacts of oil shale development on the Flat Tops lakes.)

Visibility Results and Needs

The visibility module of an AQM accounts for the impairment of visibility due to the scattering and absorption of light by fine particles and gases. The module may address plume blight, layered haze, or regional (general) haze. In general, the modules developed for plume blight are reasonable comprehensive for oil shale applications, while those for regional haze are only in their infancy.

Measurements over the oil shale tracts, as well as measurements on a regional basis [143,144], have shown that the visibility over the Utah-Colorado oil shale area is very good except during dust storms, frontal passages, and other severe weather phenomena. Reference [139] outlines

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the current visibility measurement programs in the oil shale area, along with an EPA sponsored program called the Oil Shale Visibility and Particulate Monitoring Program. This EPA program consists of the following elements:

- Measurement of visibility levels for sight paths in several directions (near Monument Peak and the Flat Tops) with telephotometers and cameras.
- Collection of particulate samples and analysis for elemental composition.
- Use of a number of methods to relate visibility and particulate data as a function of season and meteorological condition.
- Characterization of pollution source data from the technical literature, including analysis of local soil samples.
- Establishment of the relationship between emission source categories and ambient particulate levels through the use of tracers.
- Combination of visibility and particulate data on a seasonal basis in order to construct a "pie diagram" showing sources of visibility degradation for the oil shale area.

The use of the results from this EPA program, plus the results from other programs, will allow the potential visibility impacts of oil shale development to be compared with those due to other sources, such as urban areas, power plants, mineral development, and prescribed burning.

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SECTION 6

RESEARCH NEEDS

The current application of numerical simulation models to the analysis of air quality impacts due to an oil shale industry can be improved in the following ways:

- A more thorough knowledge of the scaling of emission factors from pilot, demonstration, and prototype plants to commercial size plants.
- A better accounting of the diurnal and seasonal variations of flow and temperature fields over the oil shale area.
- A more thorough understanding of the chemical and physical transformations of chemical species in the atmosphere.
- A better accounting of both dry and wet removal of gaseous and particulate pollutant species over this relatively dry and rough terrain.

By designing new and improved air quality assessment models for the oil shale area, impacts can be realistically determined and the environment can be protected.

The research needs identified in the following paragraphs will help improve our knowledge about the pollutant transport over the oil shale area, and thus improve current air quality impact modeling over the area.

Area of Influence of Upper Air Stations

The climatological data collected by the National Weather Service and archived at NCC over the Utah-Colorado oil shale area are very sparse. Figure 13 shows the location of several stations recording hourly surface data during some periods of the day and week. Four of these stations (Denver and Grand Junction, Colorado; Lander, Wyoming; and Salt Lake City, Utah) record upper air data twice daily (at 00Z and 12Z). Many surface stations only record data when the airports, at which they are sited, are open. Thus, for any one hour there are usually only 13 stations that have recorded wind, temperature, humidity, and precipitation data in our area of interest. Hence, the NWS data coverage of the oil shale area is indeed very poor. Better coverage is certainly required.

The NWS data supplemented by special field programs can be used to generate regional wind and temperature fields over the Utah-Colorado oil shale area. These regional fields when coupled to the local wind and temperature fields can be used to simulate the dispersion of pollutants over the area. The construction of these fields from currently available data, at best, produces a crude approximation of the distribution of wind and temperature over the area. One way to improve these simulated wind and temperature fields is to maximize and optimize the use of the most representative data in the area, namely, the four upper air stations.

Better use of the upper air data will result if the area of influence (i.e., spatial representativeness) of each station is known. This area of influence for a given station is certainly a function of the height above the station, time of day, season of the year, the synoptic weather situation, and the degree of cloud cover. In general, as the height above a station increases, the area of influence of the station increases. For example, the areas of influence of the four stations may overlap on the 500 mb pressure surface under the proper synoptic conditions, while near the surface the area of influence of each station will be very localized. Knowing the areas of influence of each of the upper air stations and surface stations, and the transition from the lower level winds to the upper level winds over each station will allow an investigator to construct better wind and temperature fields over the oil shale area.

Thorough Review, Synthesis and Inventory of Tract Data

The several sets of meteorological and air quality data that have been collected over the Federally-leased and private oil shale tracts have not been collected in a coordinated manner and have not been recorded or archived in a central data bank or in a consistent format. Some of the data is in the public domain, but may or may not be easily accessible, while other data are basically proprietary in nature. A thorough review and inventory of all available tract information is required. The data will not be compatible and will not be recorded in a consistent and uniform manner, but the data will give a valuable piecewise pattern of the meteorology and air quality of the region in space and time. The plan of action that should be followed in this review, inventory, and analysis of data consists of answering the following questions and implementing the stated tasks:

- Where are the data?
- In what form is the data archived?
- How can the data be accessed?
- What is the quality of the data?
- What is the quantity of data archived?
- How can the data be used to design models of pollutant dispersion?

- Perform the analyses indicated.

- Recommend improvements in types of data collected, location of collection sites, use and types of measurement systems, and storage and analysis of the data.

Local Flows, Temperature Inversions, and Scale Interactions

Local flows, such as up- and down-slope and up- and down-valley wind systems, develop when horizontal temperature gradients occur over sloping surfaces. The complex terrain of the oil shale area has sloping surfaces of various inclinations and scales. These include the large-scale Western Slope of the Rocky Mountains, the inclined slope of the Piceance Basin, the slope of the valley floor, and the slope of the valley sidewalls. Research is needed to determine which of the circulations caused by these terrain slopes are important in the transport and diffusion of pollutants, and how the circulations interact.

Closely related to the development of these circulations and the dispersion capability of the flows is the temperature structure of the atmosphere. The local circulations are driven by temperature contrasts, forced primarily by heating or cooling of air layers near the ground over the various landforms. In the case of the nocturnal circulations the existence of temperature inversions in valleys and basins allows the local flows to decouple from the flows above the topography. Thus the life cycle of temperature inversions is an important determinant of the evolution of the local flows. Specific research needs are:

- Formulate, verify and define the limits of thermodynamic models for valley inversion destruction, accounting for the mechanisms of inversion descent, the effects of valley width, temperature increases in the neutral layer above the valley inversion, changes in strength and direction of the along-valley wind systems, and variations in synoptic and cloud cover conditions.

- Analyze existing mountain meteorological data and develop a model of valley inversion buildup for the valleys of Eastern Utah and Western Colorado, accounting for the rapid buildup of inversions in the late afternoon and early evening after sunset occurs, the slower inversion buildup throughout the rest of the evening, the temperature profile shapes within the inversion, the variations of down-valley winds within the inversion, and the presence of deep snow cover within the valleys and cloud cover over the valleys.

- Study the local flows of various scales and their interactions under inversion conditions, from growth to destruction, accounting for the influences of various terrain features that may restrict or accelerate the flow.

Coupling and Decoupling of the Local Flows With the Upper Air

The mechanisms leading to the coupling and decoupling of local circulations with the upper air should be studied, with the objective of understanding the phenomena sufficiently to allow useful parameterizations to be developed as input to a regional pollution transport model. This question is of particular importance for the morning transition period when pollutants carried during the night in local flows are released to the regional flows. The areas from which the pollutants are released, and the time period over which the release occurs, are important inputs to the regional model.

In summary the research need is:

- Investigate the conditions that control the coupling-decoupling of the valley circulations with the upper layer flows, accounting for the convective boundary layer (mixing layer) that develops over the heated western slope of the Colorado Rockies, the diurnal wind and temperature cycles in the valleys, the seasonal surface cover and meteorological changes, the diurnal and seasonal changes in solar insolation, changes in cloud cover, and the orientation and spatial variations of the valleys.

Convective Boundary Layer Development

A recent summer field study has shown that on relatively cloud-free days pollutants became well-mixed in a very deep layer (to 16,000 feet MSL) over the oil shale area [92,93]. A number of mathematical models may be adopted to the dispersion of pollutants in this deep CBL. However, we are not confident of the modeling results over annual cycles, or for that matter, over diurnal cycles, because of insufficient seasonal information about the evolution of the CBL, and insufficient knowledge about the airflow in the CBL as affected by topography and synoptic influences. Irregularities in the CBL structure caused by enhanced convection over favored topographic landforms are also important.

Diffusion in Local and Regional Flows

Several research projects should be conducted in order to understand, quantify and simulate the dispersion of pollutants from the oil shale sources to the various downwind ground-based receptors. Some of these projects are given in the following list:

- Research is needed to identify the mechanisms by which oil shale process emissions and fugitive dust from tailings piles and mining operations are entrained into local flows. To the extent possible, field experiments should be conducted at the sites where such entrainment will occur, and should result in a parameterization that can be used in a regional model. Inductive scientific reasoning should then be used to discover the general factors affecting entrainment at complex terrain sites so that we can predict how entrainment will occur at new sites.

- Research is needed to investigate the diffusion of pollutants during their transport in local flows of different scales. For two years the ASCOT program has been investigating diffusion in drainage flows at a valley in California through field experiments and computer simulations. Further work must be accomplished to extend the work to other local flows.

- Research is needed to determine average dispersion coefficients for regional scale flows over complicated topography. These coefficients will depend on stability, surface characteristics, topographic features, flow separations, and internal gravity waves.

- An observational program should be initiated to determine if pollutant transport in local or regional flows is affected by air stagnation in basins or constricted valleys. The goal of this investigation should be to determine information specific to valleys and basins in the oil shale area, but, since it will not be possible to investigate all valleys in the region, an attempt should be made to determine in general the characteristics of topographic features that cause stagnations.

- Research should be conducted on a number of factors which affect the ultimate concentrations at particular ground-based receptors due to the interaction of regional scale flows with local and microscale processes. These factors include the effect of boundary layers growing over sloping ground, the effect of forests on local flows, and the effects of topographically driven zones of enhanced convection. Plume impaction on terrain obstacles in stable atmospheric flows (the focus of an ongoing EPA research program) is another example.

- Research is required to determine how gases and particulates are removed from the atmosphere or transformed during transport and how pollutants, once removed, may be resuspended. Terrain effects are expected to be important in several respects. The high altitude of the oil shale areas assures that ultraviolet radiation will be of importance in photochemical transformations. Wet deposition will be strongly affected by the regional gradient of precipitation that falls over the western slope of the Rockies. Other terrain-induced effects will also be important.

- Since NO_x and O_3 are anticipated to be important chemical pollutants from, or as a result of, a mature oil shale industry, we must determine the rate and mode of conversion of NO emissions to NO_2 concentrations, and the spatial and temporal variations of O_3 destruction over the oil shale area. Data shown in [85] indicate that the nighttime destruction of O_3 is greater in the valleys than over the mountain stations in the Piceance Basin.

Meteorological and Air Quality Monitoring Sites

We have a strong need for a rawinsonde or other upper air sounding system on the western slope of the Rockies between the Denver and Grand Junction NWS sites. It should provide upper air temperature, humidity and wind data for use in formulating airflow models and in defining basic information on the diurnal and seasonal characteristics of mixing layers and temperature inversions. It may be useful to operate this sounding system in a portable mode so we can look at the CBL growth over the Flat Tops, temperature inversions in the valleys, and other wind and temperature features over the oil shale basins. The sounding frequency, in addition to the standard 00Z and 12Z soundings at the NWS sites, should be flexible so that special studies of the diurnal changes in the CBL structure can be investigated in the appropriate seasons.

A surface station on the Flat Tops Wilderness Area is needed to provide basic information on wind direction and speed, temperature, humidity and solar radiation. The temperature information, when combined with upper air information, will allow us to estimate the characteristics of temperature inversions that form over Flat Tops. Wind and surface temperature information will also allow us to estimate the time periods when pollutants can flow up the western slope and impact the Flat Tops Area.

The strengths of down-valley pollutant carrying flows during nighttime can be determined if a number of surface meteorological stations are sited in the Colorado and White River drainages. These routine measurements can be combined with occasional tethered balloon campaigns to give better definition of the drainage flows.

The Need for a Management Strategy

To carry out the research needs enumerated in this section requires a detailed management strategy that evolves as these research needs are satisfied. Key elements of this strategy are:

- The plan should include efforts to appeal to Federal and State agencies and private companies for help in supporting work to meet the research needs identified.

- The progress of other research programs must be closely monitored and redundant research programs must be avoided.

- Research results from other programs must be utilized to the extent that they are transferrable to the oil shale area.

- Local scale processes provide important inputs to the regional scale model. Thus, research needs on the local scale must not be neglected.

- The regional scale model should be constructed so that research results can be easily incorporated as they become available.

- Due to the large number of research needs, a priority system must be established so that the most important needs are the first to be met. The highest priority of effort should be directed towards understanding pollutant transport in the regional flows.

- Due to the substantial lack of knowledge of the meteorological phenomena in the complex terrain of the oil shale region, it should be anticipated that new research findings will require changes in the emphasis of field experiments as the program proceeds. Flexibility must be built into the management plan so that such changes in emphasis can be made smoothly and in a timely manner.

REFERENCES

1. Duncan, D. C. and V. E. Swanson. Organic-Rich Shale of the United States and World Land Areas. U.S.G.S. Cir. 523. U. S. Government Printing Office. Washington, D.C. 1965.

2. N.E.A. The World Almanac and Book of Facts 1981. Newspaper Enterprise Association, Inc., New York, N.Y. 1981.

3. E.R.T. Proposed and Mandatory Class I PSD Area Maps. Environmental Research and Technology, Inc., Concord, Mass. 1980.

4. Anderson, S. R., et al. Wind Energy Resource Atlas: The Southern Rocky Mountain Region. PNL-3195-WERA-8. Pacific Northwest Lab., Richland, WA. March 1981.

5. Trijonis, J. and D. Shapland. Existing Visibility Levels in the U.S. (Submitted by Technology Services Corp. under Contract No. 802815). U. S. EPA., Research Triangle Park, N.C. 1978.

6. U. S. DOE Oil Shale Subcommittee. Environmental Development Plan for Oil Shale. DOE/EDP-0051. U. S. Dept. of Energy, Washington, D.C. 1979.

7. Bates, E. R. and T. L. Thoem. Environmental Perspective on the Emerging Oil Shale Industry. EPA-600/2-80-205a. U. S. Environmental Protection Agency, Cincinnati, Ohio. 1980.

8. U.S.G.S. Oil Shale Office. Oil Shale Development in the Piceance Basin and the Uinta Basin. U. S. Geological Survey. Grand Junction, CO. 1981.

9. Kronenberger, L., et al. The Impact of the Clean Air Act on Oil Shale Development: API Oil Shale Case Study Group Report. Draft report. American Petroleum Institute, Washington, D.C. 1981.

10. Hessel, D. L. and G. Strasser. Draft Final Report: Western Oil Shale Development - A Technological Assessment. PNL-3830. Pacific Northwest Laboratory, Richland, Washington. May 1981.

11. Latimer, D. A. and J. R. Doyle. Prevention of Significant Deterioration Policy Implications for Projected Oil Shale Development. Draft Final Report. SAI No. 81274. U. S. Environmental Protection Agency, Washington, D.C. 1981.

12. M.E.P. "Who's Who in Shale." Shale Country. 4(1) Mountain Empire Publ., Denver, CO. 1982. pp. 6-10.

13. M.E.P. "Exxon Mothballs Shale Project." Shale Country. 4(4). Mountain Empire Publ., Denver, CO. 1982. pp. 1-2.

14. Madonia, S. T. "Oil Shale ABCs." Shale Country. 4(1). Mountain Empire Publ., Denver, CO. 1982. pp. 11-13.

15. Speth, G., ed. Environmental Quality - 1980. Eleventh Annual Report. Council on Environmental Quality, Washington, D.C. 1980.

16. Frye, R. S. and K. C. Ayers. "Air Permits for New and Modified Sources: The Significance of June 8, 1981." J. of APCA 31. 1981. pp. 397-400.

17. Fox, D. G. and D. J. Murphy. Air Quality, Oil Shale, and Wilderness: A Workshop to Help Identify and Protect Air Quality Related Values of the Flat Tops. Draft Report. U. S. Dept. of Ag. Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO. 1981.

18. Interagency Task Force on Acid Precipitation. National Acid Precipitation Assessment Plan. Washington, D.C. (Office of the Executive Director). June 1982.

19. Bureau of National Affairs. Environmental Reporter: State Air Laws. Bureau of National Affairs, Inc., Washington, D.C. 1980.

20. Ondov, J. M. Airborne Pollutants from Oil Shale Technologies: Status of Ongoing Research at PNL, CSU and LLNL. Status Report given at U. S. DOE Review in Washington, D.C. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

21. Fruchter, J. S. and C. L. Wilkerson. "Characterization of Oil Shale Retort Effluents." Oil Shale: The Environmental Challenges. Colorado School of Mines Press, Golden, CO. 1981. pp. 31-63.

22. Atwood, M. T., et al. "Chemical and Physical Properties of Oil Shale Dust and Correlations with Laboratory Fine and Explosivity Test Results." 12th Oil Shale Symp. Colorado School of Mines, Golden, CO. April 25, 1975. pp. 1-17.

23. Executive Director's Office. Colorado Oil Shale: The Current Status. Department of Natural Resources, Colorado Geological Survey, Denver, CO. 1979.

24. TDA. Colorado West Transportation Plan. Prepared for Colorado West Area Council of Governments by TDA Inc. Seattle & Boulder. March, 1980.

25. Pace. Socioeconomic Analysis for DOE Alternate Fuels Proposal. Submitted to Occidental Oil Shale, Inc. by Pace Quality Development Assoc., Inc., Denver, CO. 1980.

26. Hall, R. E. and D. G. DeAngelis. "EPA's Research Program for Controlling Residential Wood Combustion Emissions." J. of A.P.C.A. 30. 1980. pp. 862-867.

27. Cooper, J. A. "Environmental Impact of Residential Wood Combustion Emissions and Its Implications." J. of A.P.C.A. 30. 1980. pp. 855-861.

28. Changnon, S. A. and R. G. Semonin. "Impact of Man Upon Local and Regional Weather." Reviews of Geophysics and Space Physics. 17. 1979. pp. 1891-1900.

29. Landsberg. H. "Inadvertent Atmospheric Modification Through Urbanization." Weather and Climate Modification. John Wiley and Sons, Inc., New York, N.Y. 1974. pp. 726-763.

30. National Academy of Sciences. Carbon Dioxide and Climate: A Scientific Assessment. Climate Research Board, Washington, D.C. 1979.

31. U. S. Congress, Senate Committee on Governmental Affairs. "CO_2 Symposium: Findings and Recommendations." A Symposium: Carbon Dioxide Accumulation in the Atmosphere, Synthetic Fuels and Energy Policy. 96th Congress. 1st session. U. S. Government Printing Office, Washington, D.C. 1979.

32. U. S. Department of Energy. "Carbon Dioxide and Synfuels." CO_2: Status Report: Carbon Dioxide Effects Research and Assessment Program. Department of Energy, Washington, D.C. January 1980.

33. Elliott, W. P. and L. Machta. U. S. Congress, Senate Committee on Governmental Affairs. A Symposium: Carbon Dioxide Accumulation in the Atmosphere, Synthetic Fuels and Energy Policy. 96th Cong. 1st Session. U. S. Government Printing Office, Washington, D.C. 1979.

34. Sklarew, R. C. and J. C. Wilson. Air Quality Models, Required Data Characterization. EC-137. Electric Power Research Institute, Palo Alto, CA. 1976.

35. U. S. EPA. Regional Workshops on Air Quality Modeling: A Summary Report. (Draft Report). U. S. EPA., Research Triangle Park, N.C. 1981.

36. Hayes, S. R. Control of Nitrogen Oxides: Assessment of Needs and Options, Technical Support Document. Volume 1, Introduction and Summary. EA-2048. Volume 1. Electric Power Research Institute, Palo Alto, CA. 1981.

37. Barr, S., et al. Workshop on Research Needs for Atmospheric Transport and Diffusion in Complex Terrain. CONF-7609160. Energy Research and Development Administration, Washington, D.C. 1977.

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38. Hilst, G. R. Plume Model Validation. EA-917-SY. Electric Power Research Institute, Palo Alto, CA. 1978.

39. Hovind, E. L., *et al*. Workshop on Atmospheric Dispersion Models in Complex Terrain. EPA-600/9-79-041. U. S. EPA , Research Triangle Park, N.C. 1979.

40. U.S.G.S. Digital Terrain Tapes: User Guide. 2nd Edition. U. S. Dept. of Interior, Geological Survey. The National Cartographic Information Center, Reston, Virginia. 1979.

41. U.S.D.A. Green River Basin, Wyoming. Cooperative River Basin Study. (Main Report). U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1978.

42. U.S.D.A. Generalized Land Use Map of Colorado. U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1965.

43. U.S.D.A. Colorado Map: Natural Vegetation. U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1972.

44. Colorado. Maps: Existing Land Use (1973) and Snow Depth (1974) for Colorado. Colorado Land Use Commission, Denver, CO. 1974.

45. C.S.U. Vegetation Map: Piceance Basin and Roan Plateau, Colorado. Range Science Department, Colorado State University, Fort Collins, CO. 1973.

46. U.S.D.A. Garfield County Colorado Map: Land Use and Natural Plant Communities. U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1976.

47. U.S.D.A. White River National Forest, Colorado: National Forest Visitors Map. U. S. Dept. of Agriculture Forest Service, Forest Supervisor, Glenwood Springs, CO. 1979.

48. U.S.D.A. Flat Tops Wilderness: National Forest Visitors Map. U. S. Dept. of Agriculture, Forest Serv., Forest Supv., Glenwood Springs, CO. 1979.

49. U.S.D.A. Utah Map: Irrigated and Dryland Farming Areas. U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1959.

50. U.S.D.A. Utah Map: Vegetative Types and Land Resource Areas. U. S. Dept. of Agriculture, Soil Conservation Service, Portland, OR. 1977.

51. E.D.C. Utah and Colorado Oil Shale Site Contour Maps. Energy Development Consultants, Inc., Denver, CO. 1979.

52. U. S. Congress. Office of Technology Assessment. An Assessment of Oil Shale Technologies. U. S. Government Printing Office, Washington, D.C. 1980.

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EPA-287 (Cin.)
(4-76)

53. Brown, R. D., ed. Health and Environmental Effects of Synthetic Fuels Technologies: Research Priorities. MTR-80W348. The MITRE Corp., McLean, VA. 1981.

54. EPA Oil Shale Research Group. Environmental Assessment: Perspective on the Emerging Oil Shale Industry. EPA 625/9-81-005. U. S. EPA, Cincinnati, Ohio. 1981.

55. DOE. Oil Shale Surface Retorting: Environmental Characterization Information Report. DOE/EP-0015. U. S. Dept. of Energy, Washington, D.C. 1981.

56. Burnham, A. K., et al. Hydrogen Sulfide Evaluation from Colorado Oil Shale. UCRL-84066 R.I. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

57. Holland, L. M. and C. G. Stafford. The Los Alamos Integrated Oil Shale Health and Environmental Program: A Status Report. LA-8665-SR. Los Alamos National Laboratory, Los Alamos, NM. 1981.

58. Thoem, T. L. "EPA and Oil Shale." Presented at the Outlook for Oil Shale, Brown Place Hotel, Denver, CO. June 19 and 20, 1980.

59. Interagency Task Force on Oil Shale. Project Independence Blueprint. Final Task Force Report, Potential Future Role of Oil Shale Prospects and Constraints. Federal Energy Administration, Washington, D.C. 1974.

60. Brown, R., ed. Health and Environmental Effects of Oil Shale Technology. DOE/HEW/EPA-02 and MTR-79W00136. The MITRE Corporation, McLean, VA. 1979.

61. House, P. W. Technology Characterizations: Environmental Information Handbook. DOE/EV-0072. U. S. Department of Energy, Washington, D.C. 1980.

62. Williams, M. D. and C. A. Mangeng. Local Air Quality in the Four Corners Study Region. National Commission on Air Quality, Washington, D.C. 1980.

63. Anderson, G. E., et al. Air Quality Impacts of Anticipated Development in Oil Shale Operations in Western Colorado and Eastern Utah. SAI No. 155-EF80-147. Systems Applications, Inc., San Rafael, CA. August 1980.

64. Hinman, G. W. and E. M. Leonard. Air Quality and Energy Development in the Rocky Mountain West. LA-6674. Los Alamos Scientific Laboratory, Los Alamos, NM. 1977.

65. Hinman, G. W. and E. M. Leonard. Effects of Energy Development on Air Quality in the Rocky Mountain West. No. 77-33.5. Presented at 70th Annual Meeting of APCA, Toronto, Canada. June 20 - June 24, 1977.

66. Cooper, C. Air Quality and Energy Development in the Rocky Mountain West - An Update of Earlier Work. Environmental Research Center, Washington State University, Pullman, WA. April 1979.

67. Nochumson, D., et al. Potential Future Impacts on Visual Air Quality for Class I Areas. LA-UR-79-1141. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1979.

68. Dougan, P. M. BX In-Situ Oil Shale Project. (Quarterly Tech. Progress Report for 9/1/78 to 11/31/78). FE-1747-7. Prepared for U. S. DOE. Equity Oil Co., Salt Lake City, Utah. 1978.

69. Dougan, P. M. BX In-Situ Oil Shale Project. (Annual Tech. Progress Report for 3/1/79 to 2/29/80). DOE/LC/10747-11. Prepared for U. S. DOE. Equity Oil Co., Salt Lake City, Utah. 1980.

70. Dougan, P. M. BX In-Situ Oil Shale Project. (Annual Tech. Progress Report for 3/1/80 to 2/28/81). DOE/LC/10747-T1. Prepared for U. S. DOE. Equity Oil Co., Salt Lake City, Utah. 1981.

71. Nelson, R. M. Occidental Vertical Modified In-Situ Process: For the Recovery of Oil from Oil Shale, Phase II. (Quarterly Progress Report for 12/1/80 to 2/28/81.) DOE/LC/10036-T8. Prepared for U. S. DOE. Occidental Oil Shale, Inc., Grand Junction, CO. 1981.

72. Hutchinson, D. L. Investigation of the Geokinetics Horizontal In-Situ Oil Shale Retorting Process. (Quarterly Rep. for Jan., Feb., March 1981). DOE/LC/10787-77. Prepared for U. S. DOE. Geokinetics, Inc., Concord, CA. 1981.

73. Parker, G. B. Review of Air Quality Assessment Studies and Definitions of Some Research Needs for the Emerging Oil Shale Technology. PNL-2910. Pacific Northwest Laboratory, Richland, WA. 1979.

74. Wolf, M. A., et al. Parachute Creek Valley Diffusion Experiments. Final Report to Colony Development Operation. Battelle, Pacific Northwest Laboratories, Richland, WA. 1972.

75. Wolf, M. A., et al. Atmospheric Dispersion of Airborne Effluents from the Roan Plateau. Final Report (Volume 1) to Colony Development Operation. Battelle, Pacific Northwest Laboratories, Richland, WA. 1973.

76. Bander, T. J. and M. A. Wolf. Transport and Diffusion of Airborne Pollutants Emanating from a Proposed Shale Oil Production Plant. Supplemental Report to Colony Development Operation. Battelle, Pacific Northwest Laboratories, Richland, WA. 1975.

77. Legatski, M. The Colony Application for a PSD Permit for Oil Shale Operations. Colony Development Operations, Denver, CO. 1978.

78. Newman, P. American Petroleum Institute AQ3-SYNFUELS Regional Monitoring Network Station Inventory. (Ms. Pam Newman, Permit Specialist.) Multi Mineral Corp., Grand Junction, CO. 1981.

79. VTN. Final Environmental Baseline Report: Federal Prototype Oil Shale Leasing Program, Tracts U-a and U-b, Utah, White River Shale Project. VTN Colorado, Inc., Irving, CA. 1977.

80. Chan, M. W. and M. I. Smith. Long-Term Variations in Ozone Measurements in a Remote Area in Northeastern Utah. Paper No. 81-6.3. Pres. at the 74th Annual Meeting of the APCA, Phil., PA., June 21-26, 1981.

81. RBOSC. Scope of Work: Modular Development Phase: Environmental Monitoring Program Tract C-a Oil Shale Lease. Rio Blanco Oil Shale Co., Aurora, CA. 1981.

82. RBOSC. Final Environmental Baseline Report for Tract C-a and Vicinity. Rio Blanco Oil Shale Co., Aurora, CO. 1977.

83. RBOSC. Modular Development Phase: Monitoring Report Three: Dec. 1977 - Nov. 1978, Year-End Report. Rio Blanco Oil Shale Co., Aurora, CA. 1979.

84. RBOSC. Modular Development Phase: Monitoring Report Five: Dec. 1978 - Nov. 1979, Year End Report. Rio Blanco Oil Shale Co., Aurora, CA. 1980.

85. Singh, H. B., et al. Ozone from Natural and Man-Made Sources. (Final Report for Project 5661 with Coordinating Research Council). Stanford Research Institute, Menlo Park, CA. 1977.

86. EG&G. Upper Air Studies Over Federal Oil Shale Tract C-a During October 1974. AL-ECP-74-108. EG&G Environmental Consultants, Denver, CO. 1974.

87. EG&G. Upper Air Studies Over Federal Oil Shale Tract C-a During Winter 1975. AL-EC-118. EG&G Environmental Consultants, Denver, CO. 1975.

88. EG&G. Upper Air Studies for Federal Oil Shale Tract C-a: Spring 1975. ECR-75-004. EG&G Environmental Consultants, Denver, CO. 1975.

89. EG&G. Upper Air Studies Over Federal Oil Shale Tract C-a During Summer 1975. ECR-75-015. EG&G Environmental Consultants, Denver, CO. 1975.

90. EG&G. SF_6 Tracer Gas Study for Federal Oil Shale Tract C-a During October 1976. B-4479. EG&G Environmental Consultants, Waltham, MA. 1977.

91. Coffey, M. E., et al. Analysis and Interpretation of the Rio Blanco Oil Shale Tracer Study. NUS-TM-309. NUS Corp., Rockville, MD. 1977.

92. Laulainen, N. S., et al. Mixing Layer Growth and Background Air Quality Measurements Over the Colorado Oil Shale Area. PNL-SA-9358. Pacific Northwest Laboratory, Richland, WA. 1981.

93. Whiteman, C. D., et al. Meteorological Data Report for Field Studies Conducted in August 1980 in the Oil Shale Region of Northwest Colorado. PNL-3734. Pacific Northwest Laboratory, Richland, WA. 1981.

94. Clements, W. E., et al. Experimental Design and Data of the August 1980 Corral Gulch Nocturnal Wind Experiment, Piceance Basin, Northwestern Colorado. LA-8895-MS. Los Alamos National Laboratory, Los Alamos, N.M. 1981.

95. Barr, S. and W. E. Clements. Nocturnal Wind Characteristics in High Terrain of the Piceance Basin, Colorado. LA-UR-81-1929. Los Alamos National Lab., Los Alamos, N.M. 1981.

96. Sehmel, G. A. A Dual-Tracer Experiment to Investigate Pollutant Transport, Dispersion, and Particle Dry Deposition at the Rio Blanco Oil Shale Site in Colorado. PNL-SA-9327. Pacific Northwest Laboratory, Richland, WA. 1980.

97. Sehmel, G. A. Atmospheric Tracer Gas Investigations in the Colorado Oil Shale Region. PNL-SA-9834. Pacific Northwest Laboratory, Richland, WA. 1981.

98. C-b Shale Oil Project. 1979 C-b Annual Report: Environmental Analysis. Occidental Oil Shale, Inc., Grand Junction, CO. 1980.

99. C-b Shale Oil Project. 1978 C-b Annual Report: Environmental Analysis. Occidental Oil Shale, Inc., Grand Junction, CO. 1979.

100. C-b Shale Oil Project. Oil Shale Tract C-b: Environmental Baseline Program: Final Report (November 1974 through October 1976). Occidental Oil Shale, Inc., Grand Junction, CO. 1977.

101. Fosdick, G. E., et al. Air Quality on the Prototype Oil Shale Leasing Program at the Colorado C-b Tract. Paper No. 77-37.4. Pres. at 70th Annual Meeting of the APCA, held in Toronto, Canada, 20-24 June, 1977.

102. Chan, M. W. and M. I. Smith. Tracer Study at the Federal Prototype Oil Shale Lease Tract C-b in Rio Blanco, CO. AV-R-81 72. Aerovironment, Inc., Pasadena, CA. 1978.

103. Chan, M. W. A Tracer Experiment to Determine the Transport and Dispersion of an Elevated Plume in Complex Terrain. Paper No. 79-8-2. Pres. at 72nd Annual Meeting of the APCA, held in Cincinnati, Ohio, June 24-28, 1979.

104. EG&G. Upper Air Studies over Federal Oil Shale Tract C-b During October 1974. AL-ECP-74-107. EG&G Environmental Consultants. Denver, CO. 1974.

105. EG&G. Upper Air Studies over Federal Oil Shale Tract C-b During Winter 1975. AL-EC-117. EG&G Environmental Consultants. Denver, CO. 1975.

106. EG&G. Upper Air Studies over Federal Oil Shale Tract C-b During Spring 1975. ECR-75-002. EG&G Environmental Consultants. Denver, CO. 1975.

107. EG&G. Upper Air Studies over Federal Oil Shale Tract C-b During Summer 1975. ECR-75-016. EG&G Environmental Consultants. Denver, CO. 1975.

108. EG&G. Upper Air Correlation Studies for October 1974 Between Federal Oil Shale Tracts C-a and C-b and Grand Junction, CO. AL-ECP-74-109. EG&G Environmental Consultants. Denver, CO. 1974.

109. EG&G. Upper Air Comparison Studies for Winter 1975 Between Federal Oil Shale Tracts C-a and C-b and Grand Junction, CO. AL-EC-116. EG&G Environmental Consultants. Denver, CO. 1975.

110. EG&G. Upper Air Comparison Studies for Spring 1975 Between Federal Oil Shale Tracts C-a and C-b and Grand Junction, CO. ECR-75-003. EG&G Environmental Consultants. Denver, CO. 1975.

111. EG&G. Upper Air Comparison Studies Between Federal Oil Shale Tracts C-a, C-b and Grand Junction, CO: Summer 1975. ECR-75-017. EG&G Environmental Consultants. Denver, CO. 1975.

112. Meyer, L.and R. Nelson. "Adequacy of Regional Atmospheric Data for Specific Predictive Purposes in the Piceance Creek Basin." Quarterly of the Colorado School of Mines. Vol. 70(4). Golden, CO. 1975. pp. 207-222.

113. Nelson, R. "Meteorological Dispersion Potential in the Piceance Creek Basin." Quarterly of the Colorado School of Mines. Vol. 70(4). Golden, CO. 1975. pp. 223-237.

114. Fosdick, G. E. and M. W. Legatski. "Prediction of Air Quality Impacts from a Commercial Shale Oil Complex." Dispersion and Control of Atmospheric Emissions: New-Energy-Source Pollution Potential. Vol. 73 (165) AICHE Symp. Series. 1977. pp. 281-290.

115. Wolf, M. A. An Analysis of Baseline Data from Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-227-T31-5. (Prepared for U. S. DOE, Washington, D.C.) Air Resources Center, Oregon State University, Corvallis, OR. 1980.

116. Slinn, W. G. N. Analyses of Air Quality and Meteorological Baseline Data from Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-2227-T31-3, Progress Report No. 1. Air Resource Center, Oregon State University, Corvallis, Oregon. 1978.

117. Slinn, W. G. N., M. A. Wolf and T. P. Hennessey, Jr. Critique of the Meteorological and Air Quality Baseline Monitoring Program for the Prototype Oil Shale Leaseholds. RLO-2227-T31-4. Air Resources Center, Oregon State University, Corvallis, Oregon. 1978.

118. Bower, C. A. and D. L. Shearer. A Case Study of Surface Mesoscale Wind Flow During a Low Visibility-Ventilation Episode in the Salt Lake Valley. Pres. at Conf. on Urban Environ. & 2nd Conf. on Biometeorology Sponsored by Amer. Meteor. Soc., Philadelphia, PA. Oct. 31 - Nov. 2, 1972.

119. Orgill, M. M. Survey of Wind Measurement Field Programs. BNWL-2220 WIND-3. Pacific Northwest Laboratory, Richland, WA. 1977.

120. Renne, D. S. A Comparison of Atmospheric Stability Between a Valley and Mountain Site. PNL-SA-6578. Pacific Northwest Laboratory, Richland, WA. 1978.

121. Whiteman, C. D. Breakup of Temperature Inversions in Colorado Mountain Valleys. Atm. Sci. Paper No. 328, Climatology Rep. No. 80-2. Dept. of Atm. Sci., Colorado State University, Fort Collins, CO. 1980.

122. Dickerson, M. H., ed. Atmospheric Studies in Complex Studies (ASCOT) Information Survey. UCID-18572. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

123. Ferber, G. J., et al. Demonstration of a Long-Range Atmospheric Tracer System. NOAA Tech. Memo. ERL ARL-101. National Oceanic and Atmospheric Administration, Silver Springs, MD. April 1981.

124. Elliott, D. L. and W. R. Barchet. Wind Energy Resource Atlas: The Northwest Region. PNL-3195-WERA-1. Pacific Northwest Laboratory, Richland, WA. April 1980.

125. NOAA. Climates of the States: Volume II-Western States Including Alaska and Hawaii. Water Information Center, Inc., Port Washington, N.Y. 1974.

126. PEDCO. Colorado's Climate, Meteorology and Air Quality. Prepared for U. S. Dept. of Interior, Bureau of Land Management, Denver, CO. PEDCO Environmental, Inc., Cincinnati, OH. 1981.

127. Rykaczewski, D. Final Reports: Climates of the Bonneville, Wasatch, Diamond Mountain, Book Cliffs, House Range, Warm Springs, Sevier River, Henry Mountain, Price River, San Rafael, Grand, San Juan, Beaver River, Dixie. and Kanab Resource Areas. Prepared for U. S. Dept. of Interior, Bureau of Land Management, Salt Lake City, UT. Science Applications, Inc., La Jolla, CA. 1981.

128. Wymore, I. F. Water Requirement for Stabilization of Spent Shale. Ph.D. Dissertation. Dept. of Earth Resources, Colorado State University, Fort Collins, CO. 1974.

129. Rhea, J. O. Orographic Precipitation Model for Hydrometeorological Use. Atm. Sci. Paper No. 287. Colorado State University, Fort Collins, CO. 1978.

130. Fifer, S. Flat Tops Wilderness - Water Resources. U.S.D.A. Forest Service, White River National Forest, Fort Collins, CO. 1981.

131. Rilling, R. A., et al. An Indium Tracer Experiment in the Yampa River Valley. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. & U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 147-149.

132. Baskett, R., et al. Evaluations of Impact and Valley Models for Low Level Releases in Colorado Mountain Valleys. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 150-156.

133. Wood, M. C., et al. Energy Development Planning and Air Quality: A Modeling Assessment of Northwestern Colorado. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 157-160.

134. Crow, L. W. and J. A. Walker. Some Typical Air Flow Patterns Surrounding the Craig and Hayden Generating Stations. Proc. of 2nd Conf. on Mountain Meteorology. Sponsored by Amer. Meteor. Soc. & U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 161-164.

135. Marlatt, W. E., et al. The Shape of Air Temperature Inversion Surfaces of Mountain Valleys. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 173-178.

136. Banta, R. M. The Development of the Heated Boundary Layer and Associated Flow Systems in South Park, CO. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 283-288.

137. Bader, D. C. and T. B. McKee. Simulation of the Daytime Evolution of Wind and Temperature Fields in Narrow Mountain Valleys. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 289-293.

138. Armstrong, R. L. and K. Mountains. Snowfall Forecasting in the Colorado Mountains. Proc. of 2nd Conf. on Mountain Meteor. Sponsored by Amer. Meteor. Soc. and U.S.D.A. Forest Service, Steamboat Springs, CO. Nov. 9-12, 1981. pp. 386-390.

139. Pitchford, A., et al. Determining Oil Shale Impact: A Visibility and Particle Monitoring Program. (Draft Report). U. S. EPA, Las Vegas, NV. 1981.

140. BLM. Project Management Plan for Synfuels Development in the Uintah Basin Region. U. S. Bureau of Land Management, Utah State Office, Salt Lake City, UT. 1981.

141. Holzworth, George C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. AP-101. U. S. EPA, Research Triangle Park, N.C. January 1972.

142. Whiteman, C. D. and R. L. Drake. The Green River Ambient Model Assessment Program: Progress Report on Local Scale Modeling Activities. PNL-4058. Pacific Northwest Laboratory, Richland, WA. 1981.

143. Henderson, R. G., ed. Research Guidelines for Regional Modeling of Fine Particulates, Acid Deposition and Visibility. MTR-80W00148. The MITRE Corp., McLean, VA. 1980.

144. Males, R. "R & D Status Report of Energy Analysis and Environmental Division: Visibility Impairment." EPRI Journal. 11. 1980. pp. 49-50.

APPENDIX A

ANNOTATED BIBLIOGRAPHY OF LITERATURE AND DATA APPLICABLE TO THE OIL SHALE AREA

The annotated bibliography given in this appendix gives some of the more important data and information sources that are directly related to the air quality impact of the emerging oil shale industry. The 88 references listed in this appendix are divided into 11 categories. Category K provides a review of other programs providing present and future information related to model development for sources in complex terrain such as in the region of the emerging oil shale industry.

A. General Environmental Studies.
B. Status of the Oil Shale Tracts.
C. General Bibliographies.
D. Source Data and Information.
E. Terrain Data and Information.
F. Climate and Meteorological Data.
G. Local Flow and Diffusion Studies in Colorado and Utah.
H. Visibility.
I. Air Quality Related Values.
J. Health and Socioeconomic Impacts.
K. Flow and Diffusion Model Development and Model Performance.

A. GENERAL ENVIRONMENTAL STUDIES

1. Bates, E. R. and T. L. Thoem (1980). Environmental Perspective on the Emerging Oil Shale Industry. EPA-600/2-80-205a. U. S. EPA, Cincinnati, OH.

2. Loose, V. (1980). Some Implications of Accelerated Synthetic Fuels Development in the Rocky Mountain States. LA-8588-MS. Los Alamos Scientific Laboratory, Los Alamos, NM.

3. EPA Oil Shale Research Group. Environmental Assessment: Perspective on the Emerging Oil Shale Industry. EPA-625/9-81-005. U. S. EPA, Cincinnati, OH. 1981.

4. Hessel, D. and G. Strasser (1981). Western Oil Shale Development: A Technology Assessment. PNL-3830. Vol. 1 to 9. Pacific Northwest Laboratory, Richland, WA.

5. ESCOE. Synthetic Fuels Summary. DOE/ET/10679-T10. Engineering Societies Commission on Energy, Inc., Washington, DC. 1981.

6. Middleton, J. T. (Chairman) (1981). On the Prevention of Significant Deterioration of Air Quality. National Academy Press, Washington, DC.

7. API Oil Shale Case Study Group. The Impact of the Clean Air Act on Oil Shale Development. American Petroleum Institute, Washington, DC. 1981.

8. U. S. DOE. Oil Shale: The Environmental Challenges. Proc. of an International Symposium held in Vail, CO. on 11-14 August, 1980. Publ. by Colorado School of Mines Press, Golden, CO. 1981.

9. Hinman, G. and E. Leonard (1977). Air Quality and Energy Development in the Rocky Mountain West. LA-6674. Los Alamos Scientific Laboratory, Los Alamos, NM.

10. Williams, M. D. and C. A. Mangeng (1980). Local Air Quality in the Four Corners Study Region. (Rough Draft). Los Alamos Scientific Laboratory, Los Alamos, NM.

11. Latimer, D. A. and J. R. Doyle (1981). Prevention of Significant Deterioration Policy Implications for Projected Oil Shale Development. (Contract No. 68-01-5845). U. S. EPA, Washington, DC.

12. Latimer, et al. (1982). Uintah Basin Synfuels Development Technical Report. Air Quality. Systems Applications Inc., San Rafael, CA.

13. Anderson, G. E., et al. (1981). Air Quality Impacts of Anticipated Developments in Oil Shale Operations in Western Colorado and Eastern Utah. SAI 155R-EF81-59, Systems Applications, Inc., San Rafael, CA.

14. Katterson, A. M. and P. E. Gallagher (1981). Screening Analysis of Ambient Air Quality Impact from Oil Shale Development in Western Colorado. Rep. No. 560RM165. Gulf Science and Technology Co. Technology and Materials Dept., Pittsburgh, PA.

15. OXY (1981). Occidental Oil Shale PSD Permit Submittal for Tract C-b. Occidental Oil Shale, Inc., Grand Junction, CO.

TOPIC Environmental Perspective on the Development of Oil Shale

REFERENCE #1 E. R. Bates and T. L. Thoem (1980). *Environmental Perspective on the Emerging Oil Shale Industry.* EPA-600/2-80-205a. U. S. EPA, Cincinnati, OH.

ABSTRACT Oil Shale deposits in the United States are among the richest and most extensive in the world. Estimates place total identified resources of medium and rich shales in the United States at 2 trillion equivalent barrels of oil. About 600 billion barrels are considered recoverable with present technology. This report summarizes the anticipated regulatory approach taken by the EPA toward oil shale development and is designed to serve as a reference and guide to EPA offices, Federal agencies, and private developers involved with the emerging oil shale industry.

The document conveys EPA's understanding and perspective of oil shale development by providing (1) a summation of available information on oil shale resources, (2) a summary of major air, water, solid waste, health, and other environmental impacts, (3) an analysis of applicable pollution control technology, including limitations, (4) a guide for the sampling, analysis, and monitoring of emissions, effluents, and solid wastes from oil shale processes, (5) suggestions for interim objectives for emissions, effluents, and solid waste disposal, and (6) a summary of oil shale technology, emissions, and effluents. The report provides a brief yet thorough discussion of the environmental problems of oil shale development.

TOPIC	Implications of Synfuel Development
REFERENCE #2	V. Loose (1980). Some Implications of Accelerated Synthetic Fuels Development in the Rocky Mountain States. LA-8588-MS. Los Alamos Scientific Laboratory, Los Alamos, NM.
ABSTRACT	A regionalized national energy model is used to examine the air quality and water quantity implications of accelerated synthetic fuels development. Several alternate targeted output levels are analyzed. Generally, the results indicate that a relatively large synthetic fuels industry (2.5 million bbl/day) could be located within the Rocky Mountain and Northern Great Plains States within the confines of water availability and air quality legislation.

TYPING GUIDE SHEET

TOPIC: Environmental Considerations of the Emerging Oil Shale Industry

REFERENCE #3: EPA Oil Shale Research Group (1981). Environmental Assessment: Perspective on the Emerging Oil Shale Industry. EPA-625/9-81-005. U. S. EPA, Cincinnati, OH.

ABSTRACT

When energy and material resources are extracted, processed, converted, and used, the effects of related pollution on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory in Cincinnati is engaged in developing and demonstrating new and improved methods that will meet these needs efficiently and economically.

This report provides a brief summary of a more comprehensive report, Environmental Perspective on the Emerging Oil Shale Industry (EPA 600/2-80-205). The full report provides a preliminary overview of environmental considerations related to the emerging oil shale industry. The report and similar ensuing reports are intended to develop the technical basis for eventual regulations.

The full report:

- Summarizes available information on oil shale resources
- Summaries major air, water, solid waste, health, and other environmental impacts
- Analyzes applicable pollution control technology
- Provides guidance for sampling, analyzing, and monitoring emissions, effluents, and solid wastes from oil shale processes

The report emphasizes those environmental impacts and control technologies that EPA believes will be of major importance.

Further information on the subjects of this report can be obtained from the Energy Pollution Control Division, Industrial Environmental Research Laboratory, Cincinnati, Ohio 45268.

TOPIC

Technology Assessment of Western Oil Shale Development.

REFERENCE #4

D. Hessel and G. Strasser (1981). Western Oil Shale Development: A Technology Assessment. PNL-3830. Vol. 1 to 9. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

The U.S. Department of Energy (DOE), Office of the Assistant Secretary for Environmental Protection, Safety, and Emergency Preparedness (EP), Office of Environmental Assessments, has been conducting technology assessments of the evolving energy technologies. The purpose of these is to evaluate in as quantitative a manner as possible the potential environmental, health and socioeconomic impacts of each technology as it moves towards commercialization. The assessments identify where further information is needed, provide an analysis of potential environmental, health, and socioeconomic consequences of each technology, and define research and development (R&D) needed to ensure environmentally acceptable commercialization.

This report presents the results of a technical study conducted in support of the DOE/EP assessment, "Western Oil Shale Development: A Technology Assessment." These results have been used as a major input in the preparation of Volume 1, the Main Report. The list of parts of the assessment report and the topics covered are as follows:

Volume 1.	Main Report
Volume 2.	Technology Characterization and Production Scenarios
Volume 3.	Air Quality
Volume 4.	Solid Waste
Volume 5.	Ground Water
Volume 6.	Surface Water
Volume 7.	Ecology and Agriculture
Volume 8.	Health and Safety
Volume 9.	Socioeconomics.

The primary objectives of the Air Quality Task were to supply climate information for the Piceance Creek Basin and to describe the effects that a mature oil shale industry (300,000 BPD) would have on the air quality over the Green River Oil Shale Formation of Colorado, Utah, and Wyoming. This task was designed to simulate air quality with models and to supply air quality data and climate data to other members of the assessment team--precipitation data to the Surface Water Task, and climate and air quality data to the Ecosystems and Agricultural Impacts Tasks.

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TOPIC Synfuels: Technologies and Energy Resources

REFERENCE #5 ESCOE (1981). Synthetic Fuels Summary. Engineering Societies Commission on Energy, Inc., Washington, DC. (DOE/ET/10679-T10).

ABSTRACT

This report examines the federal government's experience in synfuels, the market potential of synfuels, the US energy resources base, and the numerous technologies available. Technologies and energy resources are reviewed and compared to provide the facts needed to understand existing energy-related problems. This introductory manual is an overview of synfuel technologies, and markets. It is not meant to be the sole source of information on which multi-billion dollar investment decisions for specific synfuel plants would be based. The report, published originally in August 1980, has been revised to incorporate appropriate corrections and clarifications. The intent behind these revisions is to present the best technical and programmatic information available as of the original publication date, August 1980. The original report included certain information about the relative costs of selected synfuels technologies. Economics are especially sensitive to recent events and updated information, and it would possibly be misleading to restate the original cost data in this report. It was felt that the original cost data needed major updating and reconciliation due to differences in project scope, basic assumptions, and costing methodologies. ESCOE believes that reliable economic comparisons require timely data and a recognition of any major differences in scope or methodology. Therefore, ESCOE, in a separate task, is undertaking an updated commercial scale economic comparison of selected synfuel processes, on a normalized basis. The results of this task will be published as a separate ESCOE report.

TYPING GUIDE SHEET

TOPIC NAS Report on PSD Implications

REFERENCE #6 J. T. Middleton (Chairman). 1981. On the Prevention of Significant Deterioration of Air Quality. National Academy Press, Washington, DC.

ABSTRACT

The Clean Air Act Amendments of 1977 (PL 95-95, 91 Stat. 731) established a national program to prevent significant deterioration of air quality (PSD) where the air is relatively clean. The amendments also mandated two independent studies of the PSD provisions of the Act, one to be performed by the National Commission on Air Quality and one by the National Academy of Sciences. This report contains the findings, conclusions, and recommendations of the Academy's study.

The objective of our study was to examine the implementation of the PSD provisions, with special emphasis on the extent to which they make sense in light of current scientific and technical knowledge. This report therefore examines what is known about the air quality related values that the PSD provisions were established to protect (Chapter 2); describes the applicability and limitations of air quality models for use in preconstruction review (Chapter 3); discusses the potential effects of the PSD provisions on siting of major emitting facilities and on industrial development (Chapter 4); addresses the availability of control technology for PSD purposes (Chapter 5); and reviews alternatives within and to the current program for achieving PSD objectives (Chapter 6). In Chapter 1 we describe the elements of the PSD program contained in the Act and elaborated in the federal regulations.

TOPIC

Impact of Clean Air Act on Oil Shale Development

REFERENCE #7

API Oil Shale Case Study Group (1981). The Impact of the Clean Air Act on Oil Shale Development. American Petroleum Institute, Washington, DC.

ABSTRACT

This study examines the effects of existing and alternative Clean Air Act legislation on development of an oil shale industry in the Piceance Basin of Colorado. The study concludes:

- The PSD increments of the Clean Air Act will limit the production of shale oil in the Piceance Basin to levels well below the resource potential.
- If the PSD increments are eliminated, shale oil production could reach a level of about 800,000 barrels per day to be attained, instead of the 400,000 barrels per day that might be attained under the present law.
- Visibility requirements in the present act may constrain production even further, but the predictive tools are, at present, inadequate to fully assess these effects.
- The CAA requirements for the use of air dispersion models are a major technical weakness in assessing air impacts of Piceance Basin shale oil plants because no validated regional complex terrain models exist.

To achieve higher production levels, this study recommends that the Clean Air Act be amended to replace the PSD increment and classification system with a program that would rely on the use of BACT for shale oil facilities and incorporate a special air quality review for the impact of these facilities on unique scenic areas. Furthermore, fugitive dust emissions should be excluded from the review process for major projects. Visibility should not be regulated until more accurate methods for assessing visibility impairment are developed. This study also recommends a program to develop a regional scale air quality dispersion model for the Piceance Basin. This program would involve collection of meteorological and baseline air quality data for use in developing a model or models to be used for assessing air quality impacts in the complex terrain of the oil shale region. This could be implemented through a joint government-industry program.

TOPIC Oil Shale: The Environmental Challenges

REFERENCE #8 U.S. DOE (1981). Oil Shale: The Environmental Challenges. Proc. of an International Symp. held in Vail, CO on 11-14 August, 1980. Publ. by Colorado School of Mines Press, Golden, CO.

ABSTRACT The topics considered in this symposium include the following:

- The Scottish shale oil industry.
- Chemical analysis of inorganic constituents of oil shale related materials.
- Characterization of oil shale retort effluents.
- Industrial hygiene concerns of oil shale development.
- Biology and toxicology of oil shale materials.
- Ecological effects of oil shale development.
- Issues and research needs of retort abandonment.
- Socioeconomic impacts of oil shale development.
- Regulatory obstacles to the oil shale industry.

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TOPIC	Air Quality in the Rocky Mountain West
REFERENCE #9	G. Hinman and E. Leonard (1977). Air Quality and Energy Development in the Rocky Mountain West. LA-6674. Los Alamos Scientific Laboratory, Los Alamos, NM.
ABSTRACT	Current ambient air quality standards in the six Rocky Mountain states have been used to evaluate limits on the number of energy conversion facilities that can be constructed in nine resource areas in these states. Facilities considered were coal-fired power plants, coal gasification plants, and shale oil extraction facilities. The number of facilities determined in this way is compared to the numbers required in 1980, 2000, and 2020 according to a regionally disaggregated national scenario. The comparison shows that present air quality standards probably will not limit coal development in the Rocky Mountains severely but that extensive oil shale development will not be possible using current facility design. Pollutant dispersion calculations have also been used to approximate the air pollution impacts of full energy development on health, property, and aesthetics in the region. The impacts will be substantial but not large compared to the cost of control equipment or the regional economic benefits generated by the energy industries. The study brought out the high value of further research and development on reducing emissions from shale oil processing facilities, on better understanding of public perception of changes in visibility, and on knowledge about pollutant transport in mountainous terrain.

TOPIC — Air Quality Study in the Four Corners Region

REFERENCE #10 — M. D. Williams and C. A. Mangeng (1980). Local Air Quality in the Four Corners Study Region. (Rough Draft). Los Alamos Scientific Laboratory, Los Alamos, NM.

ABSTRACT

For the Four Corners Study Region, a new air dispersion model was constructed consistent with the results of measurements in the region and current understanding of plume interactions with high terrain and other features, including plume buoyancy effects and partial penetrations of elevated stable layers. The model was integrated into a system that uses National Weather Service data and local topography to define winds and stabilities at any point within the Four Corners Study Region.

The model was applied to the Four Corners Study Region for the years 1980, 1987, and 1995. In addition, estimates were made for 1995 assuming a high growth scenario. The results indicated that even under the high scenario, growth could be accommodated within the region, although individual plants might require additional controls over and above those currently planned. Specific examples where more controls or restrictions might be required included a 3200-MW coal-fired plant proposed for the Craig area in Colorado, two 880-MW coal-fired power plants in the area near Capitol Reef and Canyonlands National Parks, and two oil-shale facilities using TOSCO technology.

Only in the case of the facility near Craig were large reductions in emissions required. However, even in the case of the facility near Craig, existing control technology appears capable of the required control levels.

The modeling also indicated that the existing nonattainment area near the Four Corners facility would become an attainment area with the controls planned for 1984. Thus the modeling shows attainment for the Four Corners region in 1984 followed by consumption of the increments in the Flat Tops Wilderness in the period between 1987 and 1995. In addition, the increments in Capitol Reef and Canyonlands National Parks would be consumed in 1995 under the high scenario. However, much of the region would have only a small portion of the applicable increments consumed.

TOPIC	PSD Implications for the Projected Oil Shale Development.
REFERENCE #11	D. A. Latimer and J. R. Doyle (1981). Prevention of Significant Deterioration Policy Implications for Projected Oil Shale Development. (Contract No. 68-01-5845). U. S. EPA, Washington, DC.
ABSTRACT	Air quality and visibility impacts of a projected oil shale industry were estimated using generic screening models to assess the potential restrictions on siting and emissions of the existing Prevention of Significant Deterioration (PSD) regulations and alternatives to them. Although numerous uncertainties exist with respect to many study inputs, such as the projected oil shale production capacity, emissions, and air quality modeling approaches and assumptions, several significant, though tentative, conclusions were made. Twenty-four-hour-average Class II TSP and Class I SO2 increments are likely to be restrictive on siting and/or emissions; visibility protection goals probably will not be. If Class II and short-term Class I increments are eliminated, as has been proposed, most air quality constraints on the oil shale industry will be removed.

TOPIC Environmental Impact Analysis for Uintah Basin-Air Quality

REFERENCE #12 Latimer, et al. (1982). Uintah Basin Synfuels Development Technical Report. Air Quality. Systems Applications Inc., San Rafael, CA.

ABSTRACT This report documents an analysis of air quality impacts that was performed by Systems Applications, Inc. for the Bureau of Land Management (BLM) of synthetic fuel developments in the Uinta Basin of Utah. This analysis is to support the Environmental Impact Statement (EIS) that BLM is preparing for each of five specific synthetic fuel developments and cumulative regional impacts.

The primary objective of the study was to evaluate the air quality impacts of five synthetic fuel (oil shale and tar sands) facilities proposed to be developed in the Uinta Basin: Enercor-Mono Power (Rainbow site), Magic Circle, Paraho, Syntana-Utah, and Tosco. Three additional facilities that are at a conceptual design phase--Enerco-Mono Power (PR Springs site), Geokinetics, and Sohio--were also studied in regional scenarios. The impacts associated with two levels of oil production in the Uinta Basin of 121,400 and 320,500 barrels per day were studied.

Since cumulative regional impacts were considered to be important in this study, impacts of other industrial facilities were also examined. In the Uinta Basin these included the Moon Lake power plant (units 1 and 2), White River oil shale project (100,000 barrel per day capacity), Plateau refinery, and five other small projects. In the Piceance Basin in Colorado the air quality impacts of oil shale facilities having capacities totaling 271,000 and 639,000 barrels per day were included in regional assessments. The total synthetic fuel production capacity in the Uinta and Piceance basins studied in the low- and high-oil-production scenarios was 492,000 and 1,059,500 barrels per day, respectively.

Air quality impacts in the region were previously studied by both Systems Applications and Los Alamos Scientific Laboratory. The current study provides a more detailed analysis than did the previous policy and screening analyses. The current report is based on detailed emission inventories developed by synthetic fuel developers, Systems Applications, and PEDCo Environmental; measured meteorological conditions in the region; and additional regional data such as ambient air quality, topography, and visibility.

TOPIC — Air Quality Impacts of Oil Shale Operations

REFERENCE #13 — Anderson, G. E., et al (1981). Air Quality Impacts of Anticipated Developments in Oil Shale Operation in Western Colorado and Eastern Utah. SAI 155R-EF81-59, Systems Applications, Inc., San Rafael, CA.

ABSTRACT — This study was conducted to assess the impacts of the airborne emissions from the proposed oil shale development activities, to eliminate the potential air quality impacts, and to determine their compliance with all the existing ambient air quality standards, the PSD increments, and the visibility requirements in the studied region. This report contains six chapters. Chapter 2 describes the meteorological character of the region. The results of this assessment were used to design the modeling approaches. Chapter 3 contains an analysis of the impact of the emissions on the maximum ground-level concentrations of SO_2 and TSP near the source. The EPA's VALLEY model was used for this near-source analysis. In chapter 4, SAI's Reactive Plume Model (RPM) was applied to determine the long-distance regional impacts on ambient nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and total suspended particulates (TSP) concentrations resulting from emissions from oil shale activities. The level of impacts on visibility in PSD class I areas is examined in chapter 5. Chapter 6 contains a summary of study results and a recommended approach for conducting a more detailed assessment.

TOPIC

Model Screening Analysis of The Air Quality Impacts of the Colorado Oil Shale Tracts.

REFERENCE #14

A. M. Katterson and P. E. Gallagher (1981). Screening Analysis of Ambient Air Quality Impact from Oil Shale Development in Western Colorado. Rep. No. 560RM165. Gulf Science and Technology Co., Technology and Materials Dept., Pittsburg, PA.

ABSTRACT

Estimates of air quality impact from oil shale development in Western Colorado by EPA Region VIII indicate that PSD increments could limit the size of the industry. The particulate increment was forecasted to be consumed at a total industry capacity of approximately 400,000 B/D. The sulfur dioxide increment was projected to be the controlling regulation, limiting the industry size to about 200,000 B/D. A review has been made of the key assumptions in their analyses and the sensitivity of the results to methods of data analysis and estimates of stack parameters.

Based on the key assumptions in the Region VIII EPA analysis, calculations with the valley model indicate that only 37% of the PSD increment for particulates would be consumed at a total industrial capacity of 400,000 B/D. However, the sulfur dioxide increment would be violated at an industry size of 200,000 B/D as projected in this study.

The EPA Region VIII analysis is extremely conservative. It assumes that all source plumes converge on a Class I area, the Flat Tops Wilderness. By assuming parallel wind velocity fields, the estimate of the impact of particulate emissions at a capacity of 400,000 B/D is reduced to only 10% of the PSD increment. The estimate of the impact of sulfur dioxide emissions at a capacity of 200,000 B/D is reduced to only 35% of the PSD increment.

The estimate of a limit on the future capacity of the oil shale industry is very sensitive to the estimates of emission rate and stack parameters. Errors in emission rate will result in proportional errors in the estimated concentrations. At best, the emission rates can be forecasted to within a factor of two.

The effect of ambient air quality impact from varying stack parameters were determined for particulate emissions from the Lurgi flue. Increasing stack height from 300 to 800 feet or increasing the volumetric flow from one stack proportionally to capacity will result in a reduction of the impact by two orders of magnitude at a total industrial capacity of 400,000 B/D. The trade-offs that can be made between volumetric flow, stack height and stack temperature to obtain the same air quality impact were also determined for the Lurgi flue.

TOPIC

OXY PSD Permit --- Emissions, Town Growth, Regional Transportation.

REFERENCE #15

OXY (1981). Occidental Oil Shale PSD Permit Submittal for Tract C-b. Occidental Oil Shale, Inc., Grand Junction, CO.

ABSTRACT

The relevant material in this PSD permit application is as follows:

- Chapter 3 --- Inventory of atmospheric emissions, along with the corresponding drawings and tables.
- Appendix 9 --- Regional impacts as a result of the OXY project on tract C-b.
- Appendix 13 --- Regional transportation and population studies, for Moffat, Rio Blanco, Garfield, and Mesa Counties of Colorado.

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B. STATUS OF THE OIL SHALE TRACTS

16. EPA Oil Shale Work Group (1979). EPA Program Status Report: Oil Shale 1979 Update. EPA-600/7-79-089. U. S. EPA, Washington, DC.

17. Colorado Dept. of Natural Resources (1979). Colorado Oil Shale: The Current Status. Colorado Dept. of Natural Resources. Colorado Geological Survey, Denver, CO.

18. USGS (1981). Oil Shale: Development in the Piceance Basin and the Unita Basin. U. S. Geological Survey, Oil Shale Office, Grand Junction, CO.

19. BLM (1981). Project Management Plan for Synfuels Development in the Uintah Basin Region. Bureau of Land Management, Utah State Office, Salt Lake City, UT.

20. RBOSC (1981). Scope of Work: Modular Development Phase, Environmental Monitoring Program, Tract C-a Oil Shale Lease. Rio Blanco Oil Shale Company, Aurora, CO.

TOPIC EPA Program Status Report

REFERENCE #16 EPA Oil Shale Work Group (1979). EPA Program Status Report: Oil Shale 1979 Update. EPA-600/7-79-089. U. S. EPA, Washington, DC.

ABSTRACT

This report provides the reader with an overview of current oil shale research and development (R&D) efforts being performed by EPA, or being funded by EPA monies passed-through to other Federal agencies under the five-year old 17-agency Interagency Energy/Environment R&D Program.

- Chapter 1 introduces the reader to the purpose, background and rationale behind EPA's efforts;
- Chapter 2 discusses the EPA program goals and fiscal year 1978 program funding broken out in the areas: Extraction and handling, processing, energy-related processes and effects, and overall assessments, and;
- Chapter 3 presents the scope-of-work and status for all of the ongoing projects. A table at the end of Chapter 3 summarizes these projects by presenting project title, sponsoring agency, performing organization, project duration and project contact.

Appendices are included which present world resources and development history, EPA-published reports on oil shale, general references on oil shale and a glossary of referenced terms.

TOPIC

Status of Colorado's Oil Shale Tracts

REFERENCE #17

Colorado Dept. of Natural Resources (1979). Colorado Oil Shale: The Current Status. Colorado Dept. of Natural Resources, Colorado Geological Survey, Denver, CO.

ABSTRACT

The contents of this report include the following material:

- Map of the oil shale deposits in Green River.
- Oil shale ownership in Colorado and Utah.
- An overview of the Colorado oil shale area---geography, archeology, vegetation, wildlife, water resources, air quality, energy resources, coal and uranium activity, existing land use, population, transportation, and pipelines and electric power.
- Industry's plans for oil shale development.
- Topographical maps of the sites for Union Oil, Mobil Oil, Paraho, Superior Oil, Colony, TOSCO, White River, Chevron Oil, Rio Blanco, Occidental-Tennaco, Equity, and Geokinetics.

TOPIC	Status of Oil Shale Projects
REFERENCE #18	USGS (1981). Oil Shale: Development in the Piceance Basin and the Unita Basin. U. S. Geological Survey, Oil Shale Office, Grand Junction, CO.
ABSTRACT	There are presently 15 active oil shale project sites in the tri-corner area of Colorado, Utah, and Wyoming where planning or construction of commercial facilities for extraction of oil, gas, and associated minerals from shales of the Green River Formation is under way. This report summarizes the current status of each project and shows the geographic location of each project on a fold out map. Each of the 15 projects are further described by giving the developer, the amount of resource, mining and retorting methods, and employment projections.

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TOPIC Management Plan for Synfuels Development in the Uintah Basin Region.

REFERENCE #19 BLM (1981). Project Management Plan for Synfuels Development in the Uintah Basin Region. Bureau of Land Management, Utah State Office, Salt Lake City, Utah.

ABSTRACT

The action plan is outlined in 27 steps. This action plan is somewhat general and will be refined in detail early in the work effort. The BLM Utah State Director (Utah BLM) will have the management lead and overall responsibility for the effort, including steering committee support. The BLM Office of Special Projects-Denver (OSP) will be responsible for EIS preparation. The implementation of Steps 1-14 have already begun or will begin immediately but the major EIS work in Steps 15-23 will not require extensive effort until about September 1981. The dates for Steps 24-27 will be targeted to meet the applicants expected needs, provided that right-of-way applications and suitable project descriptions are submitted by industry in a timely manner.

Step 1 - Ascertain industry participation based on letters of intent, and meetings to be followed up by receipt of formal applications, project descriptions, and funds. (Utah BLM, in coordination with Utah State representatives.)

Step 2 - Develop standard format for project description input and coordinate with industry to obtain consistent information for each project to be included (Utah BLM and OSP).

Step 3 - Establish Federal/State/Local Coordination, Input, and Guidance Group, hereafter called "Synfuels Steering Committee" (Utah BLM).

Step 4 - Formally determine how project EIS efforts should interface with leasing plans/EIS, particularly as related to blocking up existing State leases (Utah, WO BLM, DOI and Synfuels Steering Committee). Current thought is that leasing and/or land exchange will be separate efforts which can be tiered to or otherwise build on the project EIS.

Step 5 - Obtain Synfuels Steering Committee expectations based on permitting and related actions of various governmental entities (Utah BLM, OSP).

Step 6 - Formally assign EIS preparation to OSP-Denver to prepare the EIS through the Utah State Director (as advised by the Synfuels Steering Committee) (Utah BLM, WO BLM).

Step 7 - Establish project funding accounts and coordinate billing procedures with applicants (USO, OSP). Work with applicants to obtain complete project descriptive informatin (OSP).

Step 8 - Establish Project EIS Framework, First Cut Scope and First Cut Alternatives - Prepare Draft EIS Preparation Plan (OSP and Synfuels Steering Committee).

Step 9 - Review draft scope with Steering Committee and provide feedback to applicants (Utah BLM, OSP).

Step 10 - Coordinate draft scope with DOI (OSP and Utah BLM).

Step 11 - Concurrent with Step 8, determine to what extent Colorado may be involved (OSP, Utah BLM, Colorado BLM, and Synfuels Steering Committee).

Step 12 - Review baseline data and identify any needs - arrange with Synfuels Steering Committee and existing company consultants to fill data voids under third party agreement, to initiate and complete studies in short time frame (OSP).

Step 13 - Develop public participation plan and begin public involvement process (Utah BLM, and Synfuels Steering Committee).

Step 14 - Review project descriptions with applicants, carry out formal EIS scoping, complete EIS preparation plan, and begin preparation of EIS (OSP with assistance and/or review and comment by Utah BLM and Synfuels Steering Committee).

Step 15 - Conduct periodic status reviews and review preliminary draft EIS (Synfuels Steering Committee).

Step 16 - Prepare camera-ready and arrange for printing of draft EIS (OSP).

Step 17 - File draft EIS with EPA and issue for public review (Utah BLM).

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Step 18 - Hold public hearings on draft EIS (Utah BLM and OSP).

Step 19 - Receive comment letters (Utah BLM).

Step 20 - Prepare draft response to comments and final EIS changes (OSP).

Step 21 - Review draft (PFEIS) responses to comments and changes needed for final EIS (Synfuels Steering Committee).

Step 22 - Prepare camera-ready final EIS and arrange for printing (OSP).

Step 23 - File final EIS with EPA and issue for public 30-day review period prior to decision making (Utah BLM).

Step 24 - Develop draft decision document (Utah BLM and OSP).

Step 25 - Sponsor follow-up Synfuels Steering Committee meeting to discuss recommendations for presentation to the Utah State Director and Governor (Utah BLM).

Step 26 - BLM right-of-way issuance, in coordination with required actions by others at Federal/State/local levels (Utah BLM).

Step 27 - Develop plan to maintain coordination efforts as various synfuels projects come on line (Utah BLM).

TOPIC: Rio Blanco (Tract C-a) Environmental Monitoring Program

REFERENCE #20: RBOSC (1981). Scope of Work: Modular Development Phase, Environmental Monitoring Program, Tract C-a Oil Shale Lease. Rio Blanco Oil Shale Company, Aurora, CO.

ABSTRACT

The Tract C-a lease stipulates that a monitoring program shall be conducted before and during development operations, to provide 1) a record of changes from pre-development environmental conditions; 2) an ongoing check of compliance with lease provisions and applicable federal, state, and local environmental control requirements; 3) timely recognition and notice of any adverse impacts; and 4) a factual basis for revision of lease stipulations. The monitoring program is designed to meet these stipulations as well as to satisfy the specific monitoring requirements requested by the OSO.

The environmental monitoring program is also designed to provide an indication of how successful, in fact, the planned mitigation measures prove to be. To test the success of planned mitigation measures, RBOSC will monitor the type, severity, and duration of cumulative impacts which result from the MIS operations and the proposed Lurgi Demonstration Project. The results of this monitoring will be the principal means of evaluating the adequacy of planned mitigation measures.

To the extent that it is practical, RBOSC will identify the source of any impacts which are detected in terms of their origin in MIS operations or the Lurgi Demonstration Project. In instances involving hydrologic and/or aquatic impacts, such identification is reasonably likely. In other instances, such as those involving air quality or terrestrial ecology impacts, such isolation of impact source is much more difficult, if not impossible.

C. GENERAL BIBLIOGRAPHIES

21. Radcliffe, K. S. and R. E. Thill (1978). "Bureau of Mines Oil Shale Data Bank." *Eleventh Oil Shale Symposium Proceedings.* Colorado School of Mines Press, Golden, CO.

22. Grissom, M.C. (Editor), 1981. *Oil Shales and Tar Sands: A Bibliography.* DOE/TIC-3367 (Suppl. 1). U. S. DOE. Technical Information Center, Oak Ridge, TN.

TOPIC — Bureau of Mines Oil Shale Data Bank

REFERENCE #21 — K. S. Radcliffe and R. E. Thill 1978. "Bureau of Mines Oil Shale Data Bank." Eleventh Oil Shale Symposium Proceedings. Colorado School of Mines Press, Golden, CO.

ABSTRACT

A computerized oil shale data bank has been created by the Bureau of Mines to collect and to evaluate literature and technical information pertinent to mining interests in oil shale, and to provide a means for efficient retrieval and dissemination of stored material. Its function is to rapidly identify and locate information to assist industry and government in the management and coordination of oil shale research in the design of environmentally acceptable mining and recovery technologies; in identifying research deficiencies; in planning and directing research; and in preventing duplication of research effort. A repository is maintained for hard-copy documents of most of the data bank citations for open-file access.

The data bank comprises five distinct sections: (1) bibliographic references, (2) patents, (3) current research projects, (4) property data, and (5) data syntheses and analyses. The first three parts supply abstracts describing oil shale reports and patents, in addition to keyword indexing to facilitate retrieval by subject. The subject categories provide a detailed breakdown into mining-related topics. The latter sections form a separate numerical data base, listing physical, mechanical, and thermal properties of oil shale and permitting subsequent synthesis and analysis of the data.

Information contained in the oil shale data bank will be made publicly available by means of Bureau of Mines Information Circulars. The structure of the computerized data bank also permits custom searching and retrieval of information on any combination of topics in the keyword list. Such services will be provided in response to inquiries from industry, universities, and government. Direct online interaction on a national network may later be possible.

TOPIC	Bibliography on Oil Shale and Tar Sands
REFERENCE #22	M. C. Grissom (Editor), 1981. Oil Shales and Tar Sands: A Bibliography. DOE/TIC-3367 (Suppl. 1). U. S. DOE. Technical Information Center, Oak Ridge, TN.
ABSTRACT	Five thousand one hundred forty-two citations of reports, journal articles, patents, conference papers and monographs resulting from research on oil shales and tar sands are presented. These citations and approximately 5100 additional citations are a part of the Department of Energy's Energy Data Base. The citations, with abstracts, are arranged by subject category. Within the categories references to reports are listed in alphanumeric order by report number. Other citations follow in inverse chronological order. Five indexes are provided: Corporate, Author, Subject, Contract Number, and Report Number.

D. SOURCE DATA AND INFORMATION

23. Cooper, J. A. (1980). "Environmental Impact of Residential Wood Combustion Emissions and Its Implications." APCA J. 30, pp. 855-861.

24. Griffiths, J. F. (1981). Literature Review of Fugitive Emission Factors for Surface Mining Activities. AV-R-81/544. AeroVironment, Inc., Pasadena, CA.

25. Sehmel, G. A. (1980). "Particle Resuspension: A Review." Environ. Internation. 4, pp. 107-127.

26. Mangeng, C. and R. Mead (1980). Sulfur Dioxide Emissions from Primary Nonferrous Smelters in the Western U.S. LA-8268-MS. Los Alamos Scientific Laboratory, Los Alamos, NM.

TOPIC	Emissions from Residential Wood Combustion.
REFERENCE #23	J. A. Cooper (1980). "Environmental Impact of Residential Wood Combustion Emissions and Its Implications." APCA J. 30. pp. 855-861.
ABSTRACT	Currently available information suggests a substantial environmental impact from residential wood combustion emissions. Air pollution from this source is widespread and increasing. Current ambient measurements, surveys, and model predictions indicate winter respirable (<2 μm) emissions from residential wood combustion can easily exceed all other sources. Both the chemical potency and deliverability of the emissions from this source are of concern. The emissions are almost entirely in the inhalable size range and contain toxic and priority pollutants, carcinogens, co-carcinogens, cilia toxic, mucus coagulating agents, and other respiratory irritants such as phenols, aldehydes, etc. This source is contributing substantially to the nonattainment of current particulate, carbon monoxide, and hydrocarbon ambient air quality standards and will almost certainly have a significant impact on potential future standards such as inhalable particulates, visibility, and other chemically specific standards. Emission from this growing source is likely to require additional expenditures by industry for air pollution control equipment in nonattainment areas.

TOPIC — Survey of Fugitive Emission Factors

REFERENCE #24 — J. F. Griffiths (1981). Literature Review of Fugitive Emission Factors for Surface Mining Activities. AV-R-81/544. AeroVironment, Inc., Pasadena, CA.

ABSTRACT

This report reviews the literature pertaining to emission factors from such key sources as surface mining, material handling and transfer, and haul road activities, and discusses estimating techniques and emissions studies.

In most cases, emission factors have been developed for a specific activity and a specific material, in order to make emission rates available for permit applications. To make the emission factors applicable to more situations, corrective terms have been included in the predictive emission equations to account for variations from one operation to another. The terms, in the majority of cases, quantify conditions of three specific types known to directly influence the emission rate. These conditions are: (1) source activity, (2) material characteristics, and (3) meteorology.

TOPIC	Particle Resuspension
REFERENCE #25	G. A. Sehmel (1980). "Particle Resuspension: A Review." Environ. Internation. 4. pp. 107-127.
ABSTRACT	Published numerical values of resuspension variables, rates, factors, and weathering half-lives are summarized. Results of the review show the great uncertainty in accurately predicting resuspension. Resuspension rates range over six orders of magnitude from 10^{-12} to 10^{-4} fraction/sec, resuspension factors over nine orders of magnitude from 10^{-10} to over $10^{-2}\ m^{-1}$, and weathering half-lives from 35 days to years. Data are yet needed to evaluate resuspension changes as a function of pollutant particle properties, including chemical composition, solubility, and shape.

TOPIC	SO_2 Emissions from Primary Nonferrous Smelters---Western U.S.
REFERENCE #26	C. Mangeng and R. Mead (1980). Sulfur Dioxide Emissions from Primary Nonferrous Smelters in the Western U.S. LA-8268-MS. Los Alamos Scientific Laboratory, Los Alamos, NM.
ABSTRACT	The greatest source of sulfur dioxide emissions in the West has been the pyrometallurgical processing of copper, lead, and zinc ores. Until the early '70's, the emissions from most nonferrous metal smelters were released without control into the environment. However, recent federal and state legislation have mandated the need for large reductions of emissions, a task that will require the introduction of highly efficient sulfur dioxide control technology. The particular processes at each smelter, the smelter location, the capital and operating costs including the cost of energy, the resolution of currently litigated issues, and the metal market prices will be major influences on the choice of technology and on the schedule for implementation of smelter control plans. This report examines these parameters and describes the problems and issues associated with them. The future impact of smelter sulfur dioxide emissions is discussed within the framework of the relevant economic, technological, and legal issues. (A map of the smelters is included in the report.)

E. TERRAIN DATA AND INFORMATION

27. USGS (1979). Digital Terrain Tapes: Users Guide, 2nd Edition. U.S. Dept. of Interior. Geological Survey. The National Cartographic Information Center, Reston, VA.

28. USDA (1978). Green River Basin, Wyoming. Cooperative River Basin Study. Main Report. U.S. Dept. of Agriculture, Soil Conservation Service, Portland, OR.

TOPIC Digital Terrain Tapes

REFERENCE #27 USGS (1979). Digital Terrain Tapes: Users Guide, 2nd Edition. U.S. Dept. of Interior. Geological Survey. The National Cartographic Information Center, Reston, VA.

ABSTRACT

The National Cartographic Information Center (NCIC) handles public distribution of digital terrain tapes produced by the Defense Mapping Agency Topographic Center (DMATC) from the 1:250,000-scale series of maps. The tapes, digital representations of terrain elevations, are an invaluable yet relatively inexpensive aid for regional terrain and land use studies.

The accuracy of the digital terrain tapes is no better than the accuracy of the stable-base 1:250,000-scale map sheets from which they were digitized. Neither the maps nor the tapes have been completely tested for vertical accuracy. However, the computer interpolation between contours on the map to produce a matrix of equally spaced elevation values is more consistent than manual interpolation. The Geological Survey does not assume any responsibility for the accuracy of the tapes but information on the expected accuracy of specific tapes can be obtained from NCIC. The Digital terrain data in NCIC's library is recorded on multifile 9-track magnetic tape volumes. The recording is usually done in odd parity at 1600 bpi. Each data file represents elevations for a planimetric grid of points covering part (usually one half) of a 1:250,000-scale map sheet. Within each file, data are arranged in sequential logical records. Three types of logical record formats are used.

TOPIC

Land Use, Fish and Wildlife, and Water Resources in the Green River Basin, Wyoming.

REFERENCE #28

USDA (1978). Green River Basin, Wyoming. Cooperative River Basin Study. Main Report. U.S. Dept. of Agriculture, Soil Conservation Service, Portland, OR.

ABSTRACT

The Wyoming Green River Basin Study was a cooperative federal, state, and local study. Study participants consisted of USDA agencies--Soil Conservation Service; Economics, Statistics and Cooperatives Service; and Forest Service; and the Wyoming State Engineer's Office. Other state and federal agencies, basin residents, and local governmental units also assisted in the study by providing information and suggestions which helped define land and water resource problems and objectives.

The purpose of this study was to define the magnitude of water and land resource problems and to suggest alternative plans for use in facilitating the coordinated and orderly conservation, utilization and management of water and related land resources of the basin. This study did not attempt to identify or quantify all of the land and water resource problems in the basin. It does, however, address important selected problems identified in the rural watershed areas for which USDA has programs for providing technical and monetary assistance toward solutions for all or part of the problem, such as:

- Shortage of late season irrigation water on meadow hayland and pasture.
- Salt loading in the Green River from three major tributaries--the Big Sandy and Blacks Fork Rivers and the Henrys Fork drainage.
- Inefficient use of irrigation water on irrigated pasture and hayland.
- Low production and underutilization of wood fiber.
- Erosion in excess of one-half ton per acre from rangeland and accelerated streambank erosion.
- Substandard condition and insufficient supply of recreation facilities; particularly campgrounds, wilderness trails, and boating and fishing access to streams.

- Unused available Colorado River Compact water.

- Shortage of winter livestock forage.

- Deterioration of scenic stream corridors and other landscapes.

- Insufficient identification and management of archeological, fossil and historic resources.

- Loss or deterioration of fish habitat.

- Loss or deterioration of wildlife habitat.

F. CLIMATE AND METEOROLOGICAL DATA

29. Furman, R. W. and G. E. Brink (1975). The National Fire Weather Data Library: What it is and How to Use It. USDA Forest Service, Gen. Tech. Rep. RM-19. Rocky Mt. Forest and Range Exp. Station, Fort Collins, CO.

30. Changery, M. J., et al (1977). Index-Summarized Wind Data. BNWL-2220 & WIND-11. Battelle, Pacific Northwest Laboratory, Richland, WA.

31. Changery, M. J. (1978). National Wind Data Index: Final Report. HCO/T1041-01. U.S. Dept. of Commerce. NOAA. National Climate Center, Asheville, NC.

32. Elliott, D. L. and W. R. Barchet (1980). Wind Energy Resource Atlas: Volume 1-The Northwest Region. PNL-3195 & WERA-1. Pacific Northwest Laboratory, Richland, WA.

33. Anderson, S. R., et al (1981). Wind Energy Resource Atlas: Volume 8-The Southern Rocky Mountain Region. PNL-3195 & WERA-8. Pacific Northwest Laboratory, Richland, WA.

34. PEDCO (1981). Colorado's Climate, Meteorology and Air Quality. PEDCO Environmental, Inc., Cincinnati, Ohio. (Prepared for U.S. Dept. of Interior, Bureau of Land Management, Denver, CO).

35. Rykaczewski, D. (1981). Final Reports: Climates of the Bonneville, Wasatch, Diamond Mountain, Book Cliffs, House Range, Warm Springs, Sevier River, Henry Mountain, Price River, San Rafael, Grand, San Juan Beaver River, Dixie, and Kanab Resource Areas. Science Applications, Inc., La Jolla, CA. (Prepared for U.S. Dept. of Interior, Bureau of Land Management, Salt Lake City, UT).

36. Mayerhofer, P. M. (1980). A Precipitation Data Gridding Program: Program Description and User's Guide. SRI International, Palo Alto, CA.

TOPIC National Fire Weather Data Library.

REFERENCE #29 R. W. Furman and G. E. Brink (1975). The National Fire Weather Data Library: What it is and How to Use It. USDA. Forest Service. Gen. Tech. Rep. RM-19. Rocky Mt. Forest and Range Experimental Station, Fort Collins, CO.

ABSTRACT

The Fire Weather Data Library has been compiled and made available at FCCC and Colorado State University for scientists and resource managers who need historic weather data to support their predictions and decisions. Most of the data are from stations in forrested and/or mountainous areas not adequately covered by the National Weather Service. These data should therefore be useful in mountain and forest meteorology research.

The Data Library is accessible to all users of the USDA computer in Fort Collins, Colo. Auxiliary programs are provided as part of the Library to aid the user in retrieving data. Software is also available to allow the user to obtain an inventory of any or all of the data tapes in the Library.

A problem that has not been adequately solved is how to provide station identification information to the users. At present, if a user wants geographical information about any of the stations in the Library, he must request the information from the authors.

TOPIC Index to Summarized Wind Data.

REFERENCE #30 M. J. Changery, et al. (1977). *Index -- Summarized Wind Data.* BNWL-2220 & WIND-11. Battelle, Pacific Northwest Laboratories, Richland, WA.

ABSTRACT This index was prepared as an aid in the identification of wind summaries on file at the National Climatic Center. During the last 40 years, the Climatic Center and its predecessor agencies, the Air Weather Service, and the Naval Weather Service have prepared summaries of wind data in various formats and covering various periods of time. Many of the older summaries were produced by hand tabulating data from manuscript records while more recent tabulations were produced from digitized data. All summaries were archived at the Climatic Center; however, a complete and accurate index of these summaries was not available. The Center began development of a listing of the summaries, including identifying information such as latitude, longitude, elevation, and necessary remarks, for use by Center personnel in identifying locations to answer requester needs.

With the current emphasis on alternative energy sources, the Energy Research and Development Agency (ERDA) indicated that a published document would be very useful for informing prospective users of wind-powered generating equipment and wind-site investigators of locations with summarized wind data. Accordingly, this document was produced to aid NCC personnel and data requesters in locating stations with wind summaries, determining the period of record and identifying the data format.

This index is intended to be a guide to available summaries. It does not present the actual summaries or original wind data, but lists the locations and periods for which summaries in formats described beginning on page I-13 can be obtained from the National Climatic Center for the cost of reproduction. Additional sources of wind data, presenting only monthly mean speed, are available but not listed in this document. The majority of summaries present the frequency or percentage of observations of the wind speed in various speed classes (1-3 mph, 4-7 mph, etc.) for each of 8, 16, or 36 compass points. Data for a given number of years are presented on a monthly and/or seasonal and/or annual basis. In addition, the mean speed for each direction and for all directions is usually given. A few of the summary types were developed for wind data only. In most summaries, however, wind is only one of a number of elements available. For this index, only the wind portion is presented. Since various agencies in the past have been involved in the production of these summaries, the speed class intervals have varied and data may be in knots rather than miles per hour. Summary types generally prepared from digitized data are indicated beginning on page I-15. Information on locations without summaries but with digitized records can be obtained from the Center.

The index consists of two parts. Part 1 is a geographical list presenting all summaries for a given location. It is alphabetically in state-city order. Within a city name it is ordered by station number and within station number by the earliest month-year of the period of record. Part 2 presents the data first by summary type and within summary type in state, city, station number, and period of record order.

Copies of summaries listed can be obtained for the cost of reproduction by contacting the Director, National Climatic Center, Federal Building, Asheville, NC 28801.

TOPIC National Wind Data Index

REFERENCE #31 M. J. Changery (1978). National Wind Data Index: Final Report. HCO/T1041-01. U. S. Dept. of Commerce. NOAA. National Climate Center, Asheville, NC.

ABSTRACT This index is a concise listing of the periods of record of all available wind observations in the National Climatic Center's meteorological (data) archives for locations in the United States. Included are the periods with various types of manuscript records and autographic charts containing wind data, the approximate number of observations per day, and periods for which wind data are on magnetic tape. A brief history of standard U.S. instrumentation and available meteorological record forms is included.

For most locations, the anemometer heights are included together with dates of height changes and the instrument exposure.

The index was produced at the request of the Energy Research and Development Agency (now the Department of Energy) as part of the data base development for alternative energy sources.

Copies of records listed can be provided at cost in a number of forms including paper copy, microfilm, microfiche, and magnetic tape. Requests for data or more information should be addressed to:

Director
National Climatic Center
Federal Building
Asheville, NC 28801

TOPIC Terrain, Meteorology --- Wyoming

REFERENCE #32 D. L. Elliott and W. R. Barchet (1980). Wind Energy Resource Atlas: Volume 1 - The Northwest Region. PNL-3195 & WERA-1. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

For the purpose of assessing the national wind resource, the United States and its possessions have been divided into twelve regions. For each region, wind resource assessments are presented in the form of an atlas. The atlases depict in graphic, tabular and narrative form, the wind resource on a regional and state level. The information presented in the atlases will help guide homeowners, utilities and industry in decisions concerning the use of the wind as a source of energy.

This atlas of the wind energy resource is composed of introductory and background information, a regional summary of the wind resource, and assessments of the wind resource in each state of the region. Chapter 1 provides background on how the wind resource is assessed and on how the results of the assessment should be interpreted. A description of the wind resource on a regional scale is then given in Chapter 2. The results of the wind energy assessments for each state are assembled in this chapter into an overview and summary of the various features of the regional wind energy resource. Chapter 3 provides an introduction and outline to the descriptions of the wind resource given for each state. Assessments for individual states are presented as separate chapters beginning with Chapter 4. The state wind energy resources are described in greater detail than is the regional wind energy resource, and features of selected stations are discussed.

TOPIC	Terrain, Meteorology --- Utah and Colorado
REFERENCE #33	S. R. Andersen, et al. (1981). Wind Energy Resource Atlas: Volume 8 - The Southern Rocky Mountain Region. PNL-3195 & WERA-8. Pacific Northwest Laboratory, Richland, WA.
ABSTRACT	For the purpose of assessing the national wind resource, the United States and its possessions have been divided into twelve regions. For each region, wind resource assessments are presented in the form of an atlas. The atlases depict in graphic, tabular and narrative form, the wind resource on a regional and state level. The information presented in the atlases will help guide homeowners, utilities and industry in decisions concerning the use of the wind as a source of energy. This atlas of the wind energy resource is composed of introductory and background information, a regional summary of the wind resource, and assessments of the wind resource in each state of the region. Chapter 1 provides background on how the wind resource is assessed and on how the results of the assessment should be interpreted. A description of the wind resource on a regional scale is then given in Chapter 2. The results of the wind energy assessments for each state are assembled in this chapter into an overview and summary of the various features of the regional wind energy resource. Chapter 3 provides an introduction and outline to the descriptions of the wind resource given for each state. Assessments for individual states are presented as separate chapters beginning with Chapter 4. The state wind energy resources are described in greater detail than is the regional wind energy resource, and features of selected stations are discussed.

TOPIC Meteorology, Climate, Air Quality --- Colorado

REFERENCE #34 PEDCO (1981). Colorado's Climate, Meteorology and Air Quality. PEDCO Environmental, Inc., Cincinnati, Ohio. (Prepared for U. S. Dept. of Interior, Bureau of Land Management, Denver, CO.)

ABSTRACT The Bureau of Land Management (BLM) has 11 resource areas comprising four districts in the State of Colorado, and manages approximately 8.3 million acres. Bureau efforts include the preparation of planning analyses such as: environmental statements, unit resource analyses, and environmental assessment record sections. Climate and air quality are increasingly important factors in the preparation of these analyses. Full evaluation of factors requires a description of baseline (current) climate, dispersion meteorology, air quality, and emissions. This report is designed to provide BLM with existing climate and air quality information that can be used with other resource data to develop land-use planning strategies and decisions.

The data base used to develop this report varies considerably. The data used for some of the primary climatic parameters (temperature, precipitation, etc.) cover as much as 20 to 30 years, whereas those used for secondary climatic, dispersion, and air quality related parameters (evaporation, stability, ambient air quality, etc.) cover 5 years or less. The report presents the period of record for the parameters and assesses each parameter in terms of its temporal and spatial representativeness.

The characterization of Colorado's climate and weather provides the basis for reviewing atmospheric and environmental factors in future land-use decisions. The report presents a qualitative summary outlining the general climate and dispersion related factors for each of the 11 BLM resource areas, and it also presents additional detailed quantitative discussions when sufficient data exist for a particular parameter. Where data gaps occur, the State is discussed in terms of its three major geographic features: the eastern high plains, the mountains, and the western slopes and valleys.

Following the chapters on climate and meteorology, the report presents data on air quality and emissions. It discusses air quality in terms of the 11 resource areas and presents additional data on particle size and elemental composition when available.

A bibliography is included and provides a comprehensive listing of published and in a few cases unpublished material dealing with Colorado's climate and air quality. A summary of data sources has also been prepared to provide further assistance to the resource manager. This summary of raw and in some cases published information will direct the resource manager to additional site specific data that has not been incorporated into the report. Published information has been cross referenced with the bibliography by providing the author and date. The specific contact and organization has also been listed so the resource manager can obtain unpublished data and be updated on the status of each study. Many of the studies listed are ongoing and it is possible that additional sites have been added.

TOPIC Meteorology, Climate --- Utah.

REFERENCE #35 D. Rykaczewski (1981). Final Reports: Climates of the Bonneville, Wasatch, Diamond Mountain, Book Cliffs, House Range, Warm Springs, Sevier River, Henry Mountain, Price River, San Rafael, Grand, San Juan, Beaver River, Dixie, and Kanab Resource Areas. Science Applications, Inc., La Jolla, CA. (Prepared for U. S. Dept. of Interior, Bureau of Land Management, Salt Lake City, Utah).

ABSTRACT These documents provide baseline data on climatology for BLM lands in the various resource areas of Utah. Climatology considerations have become important factors in the establishment and execution of Federal land management policies. The purpose of these documents is to provide information which can be used with other resource information to facilitate land use planning decisions especially in predictive vegetation modeling and fire and range management. These documents are intended for use by BLM personnel in all activities involved in the management of BLM administered lands.

The data base which has been used to develop these reports comprise that available in published form from governmental, academic, and private institutions within the State. These sources of data are summarized in the appropriate sections for the following climatic parameters: temperature, frost-free season, precipitation, snowfall, evaporation, solar insolation, hail and surface winds.

These reports present data which represent meaningful (i.e., long-term) and representative time periods. The analysis of the primary climatic parameters, such as temperature and precipitation are based on a minimum of 30 years of data or the period of record of the station. Nearly all of these data have been updated through 1970. Shorter periods of record were used for the secondary climatic parameters (e.g. evaporation) due to poor data availability. Caution should be used with shorter periods of record as data may not be truly representative if given years happen to be anomalous. More recent information may be obtained from the National Climatic Center in Asheville, North Carolina, or through the State Climatologist's Office at Utah State University in Logan. The State Climatologist is currently working with the BLM on expanding the climatological data bank housed at Utah State University. Programs are being written so that BLM personnel may access the USU computer and receive very current data for various climatic parameters.

Data are presented in the text in a graphics intensive manner with heavy dependence upon charts, tables, figures and overlays. The purpose of this manner of presentation is to facilitate the use of the data by BLM personnel. A key aspect of the graphical approach includes the use of topographic overlays. Figures are scaled such that they can be used in conjunction with the overlays provided in the report jacket, in order for the reader to better grasp the interactive nature of climate parameters and topography. These figures are also the same size as the BLM Areas of Responsibility and Status Map 1:1,000,000, so that this map can be used to provide further detail, as necessary.

TOPIC — Precipitation Data Gridding Program.

REFERENCE #36 — P. M. Mayerhofer (1980). A Precipitation Data Gridding Program: Program Description and User's Guide. SRI, International, Palo Alto, CA.

ABSTRACT — This report describes a series of four computer programs which standardize records and grid hourly precipitation data available on magnetic tape for the U.S. and Canada for any year. The programs place all precipitation data into a standard format, sort the data into chronologically ordered files and grid the information into a regular geographical grid. The programs include extensive checks for valid record information. The programs provide a method for utilizing the huge amounts of precipitation data which are available. There are now over 4000 stations with digitized precipitation in the U.S. and Canada.

The purpose of the four processing programs is to provide hourly precipitation data for air quality modeling and other meteorological programs. As the series of programs now stand, they can generate data for air quality grid models which can incorporate washout into their algorithms for simulation of both wet deposition and ambient air concentrations.

G. LOCAL FLOW AND DIFFUSION STUDIES IN COLORADO AND UTAH.

37. Start, G. E., et al. (1973). Diffusion in a Canyon Within Rough Mountainous Terrain. NOAA Tech. Memo. ERL ARL-38. Air Resources Laboratory, Idaho Falls, Idaho.

38. Bander, T. J. and M. A. Wolf (1975). Transport and Diffusion of Airborne Pollutants Emanating From a Proposed Shale Oil Production Plant. Supplemental Report to Colony Development Operation, Denver, CO. Battelle, Pacific Northwest Laboratories, Richland, WA.

39. McKee, T. B. and C. D. Whiteman (1977). Components of Infrared Net Radiation in a Mountain Valley. Atm. Sci. Paper. No. 279. Dept. of Atm. Sci., Colorado State University, Fort Collins, CO.

40. Whiteman, C. D. (1980). Breakup of Temperature Inversions in Colorado Mountain Valleys. Atm. Sci. Paper. No. 328 & Climatology Rep. No. 80-2. Dept. of Atmos. Sci., Colorado State Univ., Fort Collins, CO.

41. Wolf, M. A. (1980). An Analysis of Baseline Data from Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-227-T31-5. Oregon State Univ., Air Resources Center, Corvallis, OR.

42. Whiteman, C. D. et al. (1982). Green River Air Quality Model Development: Meteorological Data-August 1980 Field Study in the Piceance Creek Basin Oil Shale Resources Area. EPA-600/S7-82-047. Environmental Sciences Research Lab., Research Triangle Park, NC.

43. Laulainen, N. S., et al. (1981). Mixing Layer Growth and Background Air Quality Measurements Over the Colorado Oil Shale Area. PNL-SA-9358. Pacific Northwest Laboratory, Richland, WA.

44. Sehmel, G. A. (1981). A Dual-Tracer Experiment to Investigate Pollutant Transport, Dispersion, and Particle Dry Deposition at the Rio Blanco Oil Shale Site in Colorado. PNL-SA-9327. Pacific Northwest Laboratory, Richland, WA.

45. Sehmel, G. A. (1981). An Atmospheric Tracer Investigation of Fugitive-Emissions Transport in the Colorado Oil Shale Region. PNL-SA-9834. Pacific Northwest Laboratory, Richland, WA.

46. Clements, W. E., et al. (1981). Experimental Design and Data of the August 1980 Corral Gulch Nocturnal Wind Experiment, Piceance Basin, Northwestern Colorado. LA-8895-MS. Los Alamos National Laboratory, Los Alamos, NM.

47. Whiteman, C. D. (1982). "Breakup of Temperature Inversions in Deep Mountain Valleys: Part I. Observations." J. of Appl. Meteor. 21. pp. 270-289.

48. Whiteman, C. D. and T. B. McKee (1982). "Breakup of Temperature Inversions in Deep Mountain Valleys: Part II. Thermodynamic Model." J. of Appl. Meteor. 21. pp. 290-302.

49. Orgill, M. M. (1977). Survey of Wind Measurement Field Programs. BNWL-2220 & WIND-3. Pacific Northwest Laboratory, Richland, WA.

TOPIC

Diffusion Studies in a Utah Canyon.

REFERENCE #37

G. E. Start, et al. (1973). Diffusion in a Canyon Within Rough Mountainous Terrain. NOAA Tech. Memo. ERL ARL-38. Air Resources Laboratory, Idaho Falls, ID.

ABSTRACT

An accelerated field measurements program was conducted to quantify atmospheric diffusion within a deep, steep-walled canyon in rough, mountainous terrain. Two principle objectives were pursued... impaction of plumes upon elevated terrain, and diffusion of gases within the canyon versus diffusion over flat, open terrain. Oil fog flow visualizations provided qualitative information; quantitative diffusion measurements were obtained using sulfur-hexafluoride gas with analysis by highly sensitive gas phase coulometric techniques. Eleven 45 to 60 minute gaseous tracer releases were conducted.

Stability category related differences in canyon diffusion versus flat terrain diffusion were found. Daytime lapse conditions showed little difference. Neutral stability tests showed five times greater dilution for canyon axial concentrations; strong inversion tests resulted in canyon plume centerline dilutions fifteen times greater than calculations using parameters derived for flat terrain. Plume effluents frequently impacted against elevated terrain. One hour total integrated concentrations measured on the canyon floor and walls compared to one minute axial concentrations collected away from the terrain showed peak-to-average concentration ratios of 1.5 to 3.

Enhanced mechanical turbulence associated with gradient windflows near the mountain tops, density flows originating in side canyons, and turbulent wakes from pronounced terrain irregularities within the canyon are believed to be some of the additional physical mechanisms affecting plume dilutions in Huntington Canyon.

The present results should be relevant, at least qualitatively, to similar deep, steep-walled canyons. They should not be applied indiscriminantly to sites with less extreme topography. Additional measurements are needed at sites in less rugged terrain.

TOPIC

Transport and Diffusion Over Colony's Oil Shale Tract.

REFERENCE #38

T. J. Bander and M. A. Wolf (1975). Transport and Diffusion of Airborne Pollutants Emanating From a Proposed Shale Oil Production Plant. Supplemental Report to Colony Development Operation, Denver, CO. Battelle, Pacific Northwest Laboratories, Richland, WA.

ABSTRACT

A broad program by the Colony Development Operation to assess the environmental impact of a proposed shale oil production plant in the vicinity of Parachute Creek -- north of Grand Valley, Colorado -- has included analyses by Battelle, Pacific Northwest Laboratories of the transport and diffusion of airborne pollutant emissions. These analyses have been supported by two experimental field investigations using tracer material and meteorological data acquisition from an instrumented tower on the Roan Plateau for a period of one year.

The proposed plant site was relocated from the canyon at the confluence of the Middle and East Middle Forks of Parachute Creek to the Roan Plateau following the first field investigation which showed the likelihood of excessive airborne pollutant concentrations from a canyon site. The second field investigation demonstrated that tracer dilution is increased substantially for the emissions on the plateau. It is inferred that pollutant concentrations would be reduced similarly.

The commonly used Gaussian plume model for atmospheric diffusion is adapted following analyses of the local diffusion meteorology and current plume rise techniques to provide pollutant concentration predictions based on expected plant emissions. The modified model's suitability for this purpose is evaluated through a comparison of predicted and observed tracer distributions. It's reliability is judged to be satisfactory within the current state-of-the-art when deposition of the tracer material is accounted for.

A UNIVAC 1108 computer was used to prepare summaries of monthly and annual mean concentrations of the pollutants and of the frequencies of occurrence of 3 hr. and 24 hr. concentrations above pre-selected levels for each month and the entire year. These mean concentrations and frequencies of occurrence are displayed on a 152-point square grid extending 12 km from the plant in the four cardinal directions. Summaries of meteorological variables and their persistence also are presented.

TOPIC

Infrared Radiation in a Mountain Valley.

REFERENCE #39

T. B. McKee and C. D. Whiteman (1977). Components of Infrared Net Radiation in a Mountain Valley. Atm. Sci. Paper. No. 279. Dept. of Atm. Sci., Colorado State University, Fort Collins, CO.

ABSTRACT

The infrared components of the surface radiation budget in a mountain valley have been investigated theoretically. Calculations were based on a set of winter and summer atmospheric soundings specifying temperature and moisture content and for two valley models including a linear valley model and a circularly symmetric valley model. Radiance and irradiance calculations are compared with similar calculations for flat terrain. Downward irradiances at the valley center were shown to be higher than for flat terrain and were due to radiation from the valley sidewalls. The largest effect was obtained for a dry winter atmosphere with the sidewalls warmer than the valley bottom. Downward irradiance was increased by 16% over the flat terrain case and the net irradiance at the valley center was decreased by 24% which would lead to a decreased surface cooling.

The enhanced downward irradiance came predominantly from 2 spectral intervals--the atmospheric window (7.8-13.4μ) and a small window at 16.3 to 20.2 microns.

TOPIC

Breakup of Mountain Valley Temperature Inversions --- Colorado.

REFERENCE #40

C. D. Whiteman (1980). Breakup of Temperature Inversions in Colorado Mountain Valleys. Atm. Sci. Paper No. 328 and Climatology Rep. No. 80-2. Dept. of Atmos. Sci., Colorado State Univ., Fort Collins, Co.

ABSTRACT

Tethered balloon observations of temperature inversion breakup have been collected in seven deep Colorado mountain valleys on clear undisturbed weather days in all seasons. By sunrise, the nocturnal inversions (for 21 case studies) build to about the level of the surrounding ridgetops. On average, inversions are 604 m deep with a vertical potential temperature gradient of .0295°K m^{-1}. The inversions are typically destroyed within 3 1/2 to 5 hours following sunrise, except when the valley is snow covered or the ground is moist. Inversions are destroyed by the growth of convective boundary layers (CBLs) over the valley floor and sidewalls, and by the descent of the top of the nocturnal inversion. The descent of the top of the inversion plays a major role in most cases. During inversion destruction, specific local wind systems are associated with layers in the vertical temperature structure profiles, but the wind structure evolution is not as consistent from day to day as the temperature structure evolution.

Three patterns of temperature structure evolution have been identified from the data. These patterns have led to a hypothesis to account for inversion destruction, in which heat and mass are entrained from the elevated inversion layer into the CBLs and are carried up the sidewalls in the slope flows. Sensible heat flux from the valley surfaces provides the energy to cause the CBLs to grow and provides the energy required to remove mass from the base of the inversion layer in the upslope flows, allowing the inversion layer to sink and warm.

Based on this hypothesis a thermodynamic model of inversion breakup has been developed. The model is composed of two coupled equations which relate the inversion descent rate and CBL ascent rate to the sensible heat flux. The primary inputs to the model are the valley width, sidewall inclination angles, the characteristics of the valley inversion at sunrise, and an estimate of sensible heat flux obtained from solar radiation calculations. The outputs, obtained by a numerical integration of the model equations, are the time-dependent heights of the valley floor CBL and the inversion top, and vertical potential temperature profiles of the valley atmosphere. The model predicts that valley inversions will be more easily destroyed if the initial inversion is shallow or weak, if the sensible heat flux is strong, or if the valley is narrow.

Model results are compared with observations of inversion breakup taken in the Eagle and Yampa Valleys in different seasons. Simulations were obtained by fitting two constants in the model (relating to the surface energy budget and energy partitioning) to the data. The model accurately simulates the evolution of vertical potential temperature profiles and predicts the time of inversion destruction. The model indicates that a substantial fraction of the heat flux is used to drive the upslope flows that cause mass to diverge from the valley and result in a sinking of the inversion. This provides a means by which the valley atmosphere is rapidly warmed through its entire depth.

TOPIC Analysis of Baseline Data

REFERENCE #41 M. A. Wolf (1980). An Analysis of Baseline Data from Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-227-T31-5. Oregon State Univ., Air Resources Center, Corvallis, OR.

ABSTRACT

Data acquired by lessees of three federally leased oil shale tracts in Colorado and Utah were analyzed in an effort to develop additional information which would be useful in guiding development of those extensive resources. Comparative data within each tract and among the three tracts for ozone, total suspended particulate, and a number of meteorological variables are presented. Comments are provided concerning the uneven quality of the data. The data are utilized to show that the wide variability of ozone concentration observed at the several sites on the three tracts can be attributed principally to the daily maximum mixed layer depth of the region and to the depth and intensity of the nocturnal inversion locally. Criticism is made that the baseline programs for the three tracts were pursued independently. Finally, a research program to provide new information on short and long range transport, dispersion, and removal processes in complex terrain is urged.

TOPIC Data Report for August 1980 on Tract C-a.

REFERENCE #42 C. D. Whiteman, et al. (1981). *Meteorological Data Report for Special Studies Conducted in August, 1980 in the Oil Shale Region of Northwestern Colorado.* PNL-3734. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

Special meteorological and air quality studies were conducted during August 1980 in the Piceance Basin oil shale resource area of Northwestern Colorado by the Pacific Northwest Laboratory operated for the U.S. Department of Energy by Battelle Memorial Institute. The objective of the limited field program was to collect initial data to aid in the development, calibration, and validation of a mesoscale air quality model. The specific goals of the program were to investigate the growth and characteristics of convective boundary layers that form over the area during the daytime, to characterize background pollutant levels, visibility, and atmospheric structure over the area, and to investigate, by means of tracer experiments, the dispersion and dry deposition of pollutants released in nocturnal valley drainage flows.

An instrumented DC-3 aircraft was the primary means of collecting background air quality and visibility data. It also was used to determine spatial variations in atmospheric structure over the Piceance Basin. A balloon-borne upper air sounding system was used to monitor temporal changes in convective boundary layer structure. The sondes, measuring atmospheric temperature, humidity, and winds, were released from a point near federal oil shale tract C-a, from which supporting solar and terrestrial radiation and soil temperature data were collected. Dual tracer experiments were conducted on four occasions in the shallow Corral Gulch near tract C-a using non-depositing SF_6 gas and depositing lithium-traced particles collected on two to five sampling arcs during well-defined drainage flow events.

The report presents the data from these initial field experiments. Interpretation and analysis of the data are separate tasks that were proceeding as the report was written.

TOPIC Mixing Layer Growth Over Tract C-a.

REFERENCE #43 N. S. Laulainen, et al. (1981). Mixing Layer Growth and Background Air Quality Measurements Over the Colorado Oil Shale Area. PNL-SA-9358. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

The daily growth of convective boundary layers over the complex terrain of the oil shale areas of Colorado is a prominant feature of the meteorology of the region. The development of these layers has been investigated using airsondes, rawinsondes, and aircraft. The deep growth of the layers in August, to heights in excess of 5500-m MSL on clear or partly cloudy days, is expected to have important implications for the dispersal of pollutants released in the region as the oil shale resource undergoes future development. Aircraft observations show that the present background air quality is good over the region and that pollutants, when present, become well mixed throughout the depth of the convective boundary layer. The layer therefore represents an important natural means of dilution for pollutants introduced into the atmosphere. Work is proceeding to incorporate the time-dependent CBL growth into air pollution models for the region. Further observational work is required to determine seasonal influences in CBL development, to investigate further the relationship of convective boundary layer development to the underlying terrain in the region, and to determine how the wind fields within the developing CBL are related to the topography and prevailing winds.

TYPING GUIDE SHEET

TOPIC

A Dual-Tracer Experiment on Tract C-a.

REFERENCE #44

G. A. Sehmel (1981). *A Dual-Tracer Experiment to Investigate Pollutant Transport, Dispersion, and Particle Dry Deposition at the Rio Blanco Oil Shale Site in Colorado.* PNL-SA-9327. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

Atmospheric transport and plume depletion investigations were conducted in August, 1980, with the use of dual-tracers at the Federal Oil Shale Lease Tract C-a operated by Rio Blanco in Colorado. The objectives of the experiment were to simulate pollutant transport, dispersion, and plume depletion by particle dry deposition in site-specific terrain. The tracers were nondepositing SF_6 gas and depositing lithium-traced particles.

This dual-tracer, real-time measurement technique was also directed toward measuring the minimum decrease in respirable airborne particle concentrations with distance. The minimum was measured because of the particle diameter range used, about 0.5 to 1.5 μm. Average particle plume depletion at respirable height ranged from 37 to 68% along a down-gulch distance of only 1.2-km.

TOPIC

Tracer Study on Tract C-a.

REFERENCE #45

G. A. Sehmel (1981). An Atmospheric Tracer Investigation of Fugitive-Emissions Transport in the Colorado Oil Shale Region. PNL-SA-9834. Pacific Northwest Laboratory, Richland, WA.

ABSTRACT

Atmospheric tracer experiments were conducted in July, 1981 to investigate fugitive emission transport, depletion, and air pollution monitoring site locations in the complex terrain near the Federal oil shale lease tract C-a in Colorado. Anticipating that the spent-shale disposal area could become a prime fugitive emissions source, the atmospheric tracer gas, SF_6, was released from a site in the proposed spent-shale disposal area. The release height was at respirable height.

Airborne SF_6 tracer concentrations were sampled by radio-controlled sampling stations (15 minute sampling times) and syringe-grab samplers (near instantaneous sampling times). There were 32 radio controlled sampling stations which encompassed the release site. Sampling stations were located at sites with road access and from 0.6 to 6-km (0.4 to 4 miles) from the release site. The syringe-grab samples were collected along roads, including cross-gulch traverses. Most syringe samples were collected at distances of 3 to 13-km (2 to 8 miles) from the release site.

There were four experimental time periods including two evening and two morning time periods. The evening time periods were for tracer release from 1500 to 2100 MDT (July 15) and 1800 to 2100 MDT (July 17). The morning time periods for tracer release were from 0330 to 0930 MDT (July 19) and 0300 to 1217 MDT (July 21). The SF_6 release rate was 26 kg/hr (12 lb/hr).

Results include information on:

- Site-specific cross-wind diffusion, $_y$, at respirable height.
- A time-history of pollutant concentration changes in both gulches and other terrain before, during, and after sunrise.
- Identification of major transport flow paths in the evening and morning.

- Pollutant transport over a major ridge to an adjacent drainage valley.

- Pollutant mixing and channeling in valleys and downwind of valley confluences.

- The transient behavior of pollutant flows.

- Nocturnal drainage flows acting like a dense gas layer containing the tracer and flowing along terrain depressions.

- The inappropriate selection of air pollution monitoring station sites, heights, and concentration averaging times could make assessment applications toward PSD regulations of doubtful accuracy.

TOPIC Nocturnal Flow in Tract C-a.

REFERENCE #46 W. E. Clements, et al. (1981). Experimental Design and Data of the August 1980 Corral Gulch Nocturnal Wind Experiment, Piceance Basin, Northwestern Colorado. LA-8895-MS. Los Alamos National Laboratory, Los Alamos, NM.

ABSTRACT This report summarizes the data collected by the Los Alamos National Laboratory scientists during a field test in Corral Gulch (Colorado Oil Shale Tract C-a) during August 1980. The topics discussed in the report are:

- Synoptic conditions during the tests.
- Surface data collected from electronic weather stations.
- Vertical profiles obtained from the tethersonde system.
- Acoustic sounder data.
- Vertical profiles from the pibal-minisonde system.
- Explicit tracer experiments.

TOPIC	Breakup of Temperature Inversions in Mountain Valleys --- Colorado.
REFERENCE #47	C. D. Whiteman (1982). "Breakup of Temperature Inversions in Deep Mountain Valleys: Part I. Observations." J. of Appl. Meteor. 21. pp. 270-289.
ABSTRACT	The breakup of temperature inversions in the deep mountain valleys of western Colorado has been studied by means of tethered balloon observations of wind and temperature structure on clear weather days in different seasons. Vertical potential temperature structure profiles evolve following one of three patterns. Two of the patterns are special cases of the third pattern, in which inversions are destroyed by two continuous processes--upward growth of a convective boundary layer (CBL) into the base of the valley inversion, and descent of the inversion top. The three idealized patterns are described and 21 case studies of inversion breakup following the patterns are summarized. Inversion breakup begins at sunrise and is generally completed in 3 1/2 - 5 h, unless the valley is snow covered or the ground is wet. Warming of the inversion layer is consistent with subsidence heating. An hypothesis is offered to explain the observations, stressing the role of the sensible heat flux in causing the CBL to grow and an upslope flow to develop over the sidewalls. As mass is removed from the base of the inversion layer in the upslope flows, the inversion sinks and warms.

TOPIC — Breakup of Temperature Inversions in Mountain Valleys --- Colorado.

REFERENCE #48 — C. D. Whiteman and T. B. McKee (1982). "Breakup of Temperature Inversions in Deep Mountain Valleys: Part II. Thermodynamic Model." J. of Appl. Meteor. 21. pp. 290-302.

ABSTRACT

A thermodynamic model is developed to simulate the evolution of vertical temperature structure during the breakup of nocturnal temperature inversions in mountain valleys. The primary inputs to the model are the valley floor width, sidewall inclination angles, characteristics of the valley inversion at sunrise, and an estimate of sensible heat flux obtained from solar radiation calculations. The outputs, obtained by a numerical integration of the model equations, are the time-dependent height of a convective boundary layer that grows upward from the valley floor after sunrise, the height of the inversion top, and vertical potential temperature profiles of the valley atmosphere. The model can simulate the three patterns of temperature structure evolution observed in deep valleys of western Colorado. The well-known inversion breakup over flat terrain is a special case of the model, for which valley floor width becomes infinite. The characteristics of the model equations are investigated for several limiting conditions using the topography of a reference valley and typical inversion and solar radiation characteristics. The model is applied to simulate obsevations of inversion breakup taken in Colorado's Eagle and Yampa Valleys in different seasons. Simulations are obtained by fitting two constants in the model, relating to the surface energy budget and energy partitioning, to the data. The model accurately simulates the evolution of vertical potential temperature profiles and predicts the time of inversion destruction.

TOPIC	Survey of Wind Measurement Field Programs --- Utah and Colorado.
REFERENCE #49	M. M. Orgill (1977). Survey of Wind Measurement Field Programs. BNWL-2220 & WIND-3. Battelle, Pacific Northwest Laboratories, Richland, WA.
ABSTRACT	One of the tasks in the Site Selection Program Area of the Wind Characteristics Program Element (WCPE) is to identify and catalog existing meteorological data sets which might be used for model validation and for other WCPE studies. This report identifies and briefly summarizes 139 field programs that have used wind networks (2 to 60 wind measurement sites). In general, these studies were mesoscale in areal extent; however, there is reference to some micro- and subsynoptic scale studies. The survey covered the time period from 1940 to 1977. The summary consists of the following items: state or territory; purpose of study; location of study; terrain or environment; time period of study; wind equipment and number of wind measuring sites; approximate area of study; organizations in charge of study; bibliography; and other additional information.

H. VISIBILITY.

50. APCA (1979). A Specialty Conference on: View on Visibility-Regulatory and Scientific. (Held at the Brown Place Hotel, Denver, CO on Nov. 26-27, 1979). Air Pollution Control Association, Pittsburgh, PA.

51. Henderson, R. G. et al. (1980). Research Guidelines for Regional Modeling of Fine Particulates, Acid Deposition and Visibility. MTR80W00148. (Report on a Workshop held at Port Deposit, Maryland, Oct. 29 to Nov. 1, 1979 -- Sponsored by U.S. EPA, Washington, DC). The MITRE Corp., McLean, VA.

52. Latimer, D. A. and R. G. Ireson (1980). Workbook for Estimating Visibility Impairment. EPA-450/4-80-031. U.S. EPA, Research Triangle Park, NC.

53. Ricks, N. R. et al. (1981). "An Assessment of Regional Air Quality and Visibility for Coal Development in Southern Utah." Proc. of Symp. on Intermediate Range Atm. Trans. Processes and Tech. Assessment. CONF-801064. NTIS, Springfield, VA.

54. Pitchford, A. et al (1981). Determining Oil Shale Impact: A Visibility and Particle Monitoring Program. (Draft Report). U.S. EPA, Cincinnati, OH.

55. Laulainen, N.S. (1981). Visibility Values in the Oil Shale Area. Pres. at U.S. DOE Oil Shale Air Quality and Emissions Control Program Review. Held 8-9 December 1981 at Holiday Inn in Gaithersburg, MD.

56. Mathai, C. V. et al. (1982). "Discussion of Selected Papers from the 1980 Symposium on Plumes and Visibility." Atmos. Environ. Vol. 16, No. 10.

TOPIC APCA Visibility Conference.

REFERENCE #50 APCA (1979). A Specialty Conference on: View on Visibility - Regulatory and Scientific. (Held at the Brown Place Hote, Denver, CO. on Nov. 26-27, 1979). Air Pollution Control Association, Pittsburgh, PA.

ABSTRACT The proceedings cover papers given in the following technical sessions:

- Visibility regulations.
- Visibility perception.
- Visibility field programs.
- Visibility modeling.
- Visibility monitoring.
- Intercomparison of measurement methods.
- Implications of visibility impacts.

TOPIC

Regional Considerations of Fine Particles, Acid Deposition, and Visibility.

REFERENCE #51

R. G. Henderson, et al. (1980). Research Guidelines for Regional Modeling of Fine Particulates, Acid Deposition and Visibility. MTR-80W00148. (Report on a Workshop held at Port Deposit, Maryland, Oct. 29 to Nov. 1, 1979 --- sponsored by U. S. EPA, Washington, D.C.) The MITRE Corp., McLean, VA.

ABSTRACT

A workshop on regional air pollution modeling was held on October 29 through November 1, 1979 at Port Deposit, Maryland. The workshop was sponsored by EPA's Office of Environmental Processes and Effects Research (OEPER), Energy Effects Division. The first day and a half of the workshop was devoted to a number of invited talks on the need for regional air pollution models, their data requirements and the state-of-the-art of regional models. Papers of some of the invited talks are included in Section 3.0.

The last two and a half days of the workshop were devoted to discussions of the research needs for regional models in three working groups: Fine Particulates, Acid Deposition and Visibility. In this report the recommendations of each of the working groups are detailed and an integrated set of research study guidelines are developed. The research study guidelines were formulated by combining the working group recommendations into a single set of research requirements. This was necessary because of the large amount of overlap between the working group recommendations. With perhaps some minor differences, each area requires the use of the same emissions input, the development of meteorological fields to drive the model, the same dispersion and transport components and much of the same atmospheric chemistry. The primary difference between a fine particulate model and an acid deposition model is the need for scavenging mechanisms, both in clouds and below clouds in the acid deposition model. Similarly, the primary difference between a visibility model and a fine particulate model is the need for radiative transfer methods in the visibility model.

TOPIC	Estimating Visibility Impairment.
REFERENCE #52	D. A. Latimer and R. G. Ireson (1980). Workbook for Estimating Visibility Impairment. EPA-450/4-80-031. U. S. EPA. Research Triangle Park, N.C.
ABSTRACT	This workbook is designed to provide three screening procedures to assist in determining the potential impacts of an emissions source on a Federal Class I area's visibility. It does not address the cumulative impacts of multiple sources on regional haze. A level-1 analysis involves a series of conservative screening tests to eliminate sources with little potential for visibility impairment during hypothetical worst-case meteorological conditions. If impairment is indicated, a more resource intensive level-2 analysis is warranted. If both analyses indicate impairment, a level-3 analysis using a plume visibility model should be used. Two example applications are provided; for a coal-fired power plant and a cement plant.

TOPIC	Air Quality and Visibility Due to Southern Utah Coal Development.
REFERENCE #53	N. R. Ricks, et al. (1981). "An Assessment of Regional Air Quality and Visibility for Coal Development in Southern Utah." Proc. of Symp. on Intermediate Range Atm. Trans. Processes and Tech. Assessment. CONF-801064. NTIS, Springfield, VA.
ABSTRACT	An assessment was made of potential air quality and visibility impacts from coal development and transportation in the Kaiparowits region of Utah. Three separate coal development scenarios were examined. The potential sources included the mine lease areas, a network of transportation corridors, and associated urban growth. Local modeling (≤ 20 km) utilized a sector-averaged Gaussian plume model with terrain-specific annual and worst-case short term meteorology for each of 25 sites in the study area. A mesoscale puff dispersion model was used to assess the regional (up to 160 km) impact of the combined sources for a 72 hour period in each season. A separate wind field model was used to incorporate terrain effects in the interpolation of available sequential winds data. A visual range and discoloration model was used to calculate the projected visibility impairment within the study region based on calculated regional concentration fields.

TOPIC — Visibility and Particle Monitoring Program for the Oil Shale Area.

REFERENCE #54 — A. Pitchford, et al. (1981). Determining Oil Shale Impact: A Visibility and Particle Monitoring Program. (Draft Report). U. S. EPA, Cincinnati, OH.

ABSTRACT — Development of oil shale as an energy resource in Colorado and Utah is proceeding rapidly. Increases in coal and uranium mining and power generating facilities are also expected in this region. A variety of environmental impacts are anticipated from these many development activities. This report discusses a monitoring and data interpretation project which focuses on air quality in the region, particularly as it relates to visibility.

The oil shale deposits are located on the north edge of an area with very good visibility. In the West, visibility has been shown to be highly sensitive to increases in ambient particle concentrations. On a regional scale, present concentrations of gaseous criteria pollutants (those addressed by EPA air quality standards; CO, NO_2, O_3, SO_2, with the possible exception of ozone), are low. Thus, it is expected that visibility will be the air quality parameter most severely affected by the pollution from the planned industrial developments.

The Environmental Protection Agency (EPA), Region VIII (R-8) office and the Industrial Environmental Research Laboratory, Cincinnati, and the U.S. Geological Survey (USGS) Area Oil Shale Supervisory Office have funded the EPA Environmental Monitoring System Laboratory-Las Vegas (EMSL-LV) to conduct an Air Monitoring for Oil Shale (AMOS) research study for two years, with possibility of continuation. The goal of this project is to better understand air quality, especially visibility, in the Oil Shale area by quantifying visibility and particle concentrations and evaluating air pollution formation and transport.

Responsibility for project AMOS will be allocated among several groups. EMSL-LV will provide project management and scientific and technical guidance. Monitoring and data analysis for visibility will be conducted by Lockheed Engineering and Management Services Company (LEMSCO), an EMSL-LV support contractor. Particle monitoring and data analysis will be conducted by the University of California, Davis, a LEMSCO subcontractor. Data interpretation will be a joint effort among all the groups, with EMSL-LV taking a lead coordination role. EPA R-8, EPA-IERL, and USGS are providing funding, technical review and policy guidance for the project. The U.S. Forest Service is providing technical review and policy guidance, in addition to personnel to routinely service visibility and particle monitoring sites.

TOPIC

Visibility Over the Oil Shale Area.

REFERENCE #55

N. S. Laulainen (1981). Visibility Values in the Oil Shale Area. Pres. at U. S. DOE Oil Shale Air Quality and Emission Control Program Review. Held 8-9 December 1981 at Holiday Inn in Gaithersburg, MD.

ABSTRACT

Since the passage of the Clean Air Act Amendments in 1977, the protection and preservation of scenic vistas in National Parks, wilderness areas and other federal reserve areas which have been designated with Class I status have been established as national goals. As a consequence, an increased effort in the study of visibility and visibility related values has resulted. In the past the main welfare impact related to visibility was aircraft safety, where stringent rules on take-off and landings at airports and other air traffic patterns were implemented. In practice, few curtailments in air traffic have occurred as a result of poor visibility from air pollution, whereas the occurrence of fog with its concomitant reduction in visibility have resulted in the most curtailments.

In the western United States, with the exception of the larger metropolitan areas, visibility has always been exceptionally good, especially when compared with typical eastern haze conditions. If one examines visual range isopleths for suburban/rural (non-urban) areas (e.g. those shown in Trijonis and Shapland, 1978), the region of best visibilities (>100km) is located in Nevada, Utah, Colorado, northern Arizona and New Mexico and Southwestern Wyoming. It is not entirely coincidental that many Federal Class I areas are also located in this region, since scenic vistas are among the major attractions of these areas and good visibility plays an important role in their appreciation. The major oil shale resource is located also in this region. It is therefore of considerable urgency to evaluate the possible impacts of the development of this resource on visual air quality in the region, especially in nearby parks and wilderness areas.

In this report, the author first discusses visibility in general terms and then focuses on potential problems in the Oil Shale area. The general discussion includes a few definitions, and a brief review of the causes of visibility impairment,visibility and visibility related measurements, and temporal and spatial variability of visibility. The general discussion also includes a brief overview of existing monitoring networks, calling particular attention to those stations adjacent to or within the Oil Shale region. The discussion then turns to a description of the unique features of the Oil Shale area, particularly in the vicinity of the Piceance Basin, and their implications on potential visibility impairment in neighboring Class I areas. Present monitoring programs in the region are described. The concluding remarks include some recommendations for further study.

TOPIC Papers on Plumes and Visibility.

REFERENCE #56 C. V. Mathai, et al. (1982). "Discussion of Selected Papers from the 1980 Symposium on Plumes and Visibility." Atmos. Environ., Vol. 16, No. 10.

ABSTRACT

In response to the stimulus provided by the 1977 amendments to the U.S. Clean Air Act, the science concerned with the effects of air pollution on visibility has undergone rapid development. A comprehensive overview of the state of the art was provided by the "Symposium on Plumes and Visibility: Measurements and Model Components" held at the Grand Canyon on 10-14 November 1980. Much of the material presented at that symposium was later published in the October and November 1981 issues of Atmospheric Environment.

The U.S. Congressional mandate for visibility protection has initiated a regulatory process whose approach, effectiveness, cost and ultimate success depend considerably on our ability to quantitatively relate human judgments of visibility impairment to the sources, both natural and anthropogenic, of the aerosol and gases that contribute to that impairment. The papers presented at the symposium indicated the extent to which we can now accomplish this task and pointed out areas where our understanding is lacking.

The authors of the current paper have reviewed a number of the papers published in Atmospheric Environment, along with some as yet unpublished material presented at the symposium. Their discussion encompasses 21 of the published papers, focusing on the analysis of visibility impairment and its causes. Four broad technical areas were of interest to them, and the papers they reviewed were selected to cover these areas:

1. Atmospheric visibility and human perception of visual air quality;

2. Plume dispersion, chemical transformations, and optical characteristics, and their modeling;

3. Physical, chemical, and optical characterization of regional haze; and

4. Attributing visibility impairment to pollutant sources.

I. AIR QUALITY RELATED VALUES

57. Chappell, W. R. (1979). Trace Elements in Oil Shale. Progress Report, 1976-1979. COO-4017-3. Univ. of Colorado, Boulder, CO.

58. Fritz, E. S. (1980). Potential Impacts of Low pH on Fish and Fish Populations. Rep. No. 2 on Air Pollution and Acid Rain. FWS/OBS-8040.2. U.S. Dept. of Interior, Fish and Wildlife Service, Ann Arbor, MI.

59. BLM (1980). Draft Green River-Hams Fork Regional Coal Environmental Impact Statement, Parts I and II. U.S. Dept. of Interior, Bureau of Land Management, Craig, CO.

60. Fox, D. G. and D. J. Murphy (1981). Air Quality, Oil Shale, and Wilderness: A Workshop to Help Identify and Protect Air Quality Related Values of the Flat Tops. (Draft Report). USDA, Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO.

61. Carter, J. G. et al. (1981). Monitoring Industrial Impacts: A Case Study of an Ecosystem Approach from the Oil Shale Industry. BN-SA-1361. Battelle, Pacific Northwest Laboratories, Richland, WA.

62. U.S. DOE (1982). Workshop on the Source-Receptor Relationship in Acid Precipitation: Implications for Generation of Electric Power from Coal. Held at LaJolla, CA on 18-20 January 1982.

63. Hales, J.M. (Special Editor) (1982). "Special Issue: Precipitation Chemistry." Atmos. Environ., Vol. 16, pp. 1603-1796.

TOPIC Effects of the Release of Toxic Trace Elements.

REFERENCE #57 W. R. Chappell (1979). Trace Elements in Oil Shale. Progress Report, 1976-1979. COO-4017-3. Univ. of Colorado, Boulder, CO.

ABSTRACT The overall objective of the program is to evaluate the environmental and health consequences of the release of toxic trace elements (As, B, F, Mo, Se) by shale oil production and use. Some of the particularly significant results are: The baseline geochemical survey shows that stable trace elements maps can be constructed for numerous elements and that the trends observed are related to geologic and climatic factors. Shale retorted by above-ground processes tends to be very homogeneous (both in space and in time) in trace element content. This implies that the number of analytical determinations required of processed shales is not large. Leachate studies show that significant amounts of B, F, and Mo are released from retorted shales and while B and Mo are rapidly flushed out, F is not. On the other hand, As, Se, and most other trace elements are not present in significant quantities. Significant amounts of F and B are also found in leachates of raw shales. Very large concentrations of reduced sulfur species are found in leachates of processed shale. Upon oxidation a drastic lowering in pH is observed. Preliminary data indicates that this oxidation is catalyzed by bacteria. Very high levels of B and Mo are taken up in some plants growing on processed shale with and without soil cover. These amounts depend upon the process and various site specific characteristics. In general, the amounts taken up decrease with increasing soil cover. On the other hand, we have not observed significant uptake of As, Se, and F into plants. There is a tendency for some trace elements to associate with specific organic fractions, indicating that organic chelation or complexation may play an important role. In particular, most of the Cd, Se, and Cr in shale oil is associated with the organic fraction containing most of the nitrogen-containing compounds.

TOPIC Impacts of Low PH on Fish.

REFERENCE #58 E. S. Fritz (1980). Potential Impacts of Low PH on Fish and Fish Populations. Rep. No. 2 on Air Pollution and Acid Rain. FWS/OBS-80/40.2. U. S. Dept. of Interior, Fish and Wildlife Service, Ann Arbor, MI.

ABSTRACT

The passage of the Clean Air Act and its 1977 Amendments resulted in a number of regulations to protect air quality. Incorporated in this legislation is a new responsibility for federal land managers, including the Fish and Wildlife Service, to assess and evaluate impacts of air quality degradation on "air quality related values" on certain lands under their jurisdiction. Inherent in meeting this responsibility is the need for comprehensive and current information on ecological effects of air pollution, including acidic precipitation.

Since the early 1970's ecological research in air pollution and acid rain has steadily increased and a number of ecosystem scale studies have been initiated. As the results of these studies and other topical research become available, the need exists within the Service and other groups for analysis, interpretation, and concise summaries of this information as it relates to the potential impacts to fish and wildlife resources. Potential Impacts of Low pH on Fish and Fish Populations addresses this need in part by providing up-to-date information in a format appropriate to fishery resource evaluation. The report is intended to assist biologists and decision makers in assessment of ecological impacts and enable their effective input into the regulatory process.

TOPIC

Meteorology, Climate, Air Quality, Effects --- Colorado and Wyoming.

REFERENCE #59

BLM (1980). Draft Green River-Hams Fork Regional Coal Environmental Impact Statement. Parts I and II. U. S. Dept. of Interior, Bureau of Land Management, Craig, CO.

ABSTRACT

This Environmental Impact Statement (EIS) is intended to be apart of the decision-making process, providing information to the Secretary of the Interior and the public concerning the use of national resources. It has been prepared to comply with regulations of the Council of Environmental Quality (CEQ) issued November 29, 1978 (43 FR 55978-56007), which emphasize concentration on significant issues and impacts. The Green River/Hams Fork lease study tracts are located within a twenty mile radius of Craig, CO., or within a twenty-five mile radius of Rawlins, WY.

Part I of the Study.

Section 1, Purpose and Need for Action, identifies the need for new Federal leasing in the Green River/Hams Fork region to meet national energy goals and provides background information, which puts this need in perspective. It outlines the methods used to select and combine coal mining tracts into alternatives for meeting production goals. This section also details the concerns raised by government agencies and the public. Those concerns which this EIS assess are: secondary as well as primary impacts; the wishes of adjacent landowners; reclamation; air quality; water quality; water storage, depletion and use; cultural resources; municipal funding; community facilities such as sewers, water, schools, etc.; boom town effects like mental health, crime, etc.; and the overall energy efficiency of mining coal.

Section 2, Alternatives Including the Proposed Action, presents five alternatives for environmental analysis: Maximum, High, Medium, Low, and No Action, corresponding to the levels of coal production the alternatives would provide. The Regional Coal Team, an inter-governmental committee charged with supervision of this EIS effort, has selected the High Alternative as the Preferred Alternative, which would best meet the needs for coal. The No Action Alternative is a forecast of anticipated impacts without new Federal coal leasing against which the magnitude of the impacts of the other alternatives can be measured.

Section 3, Affected Environment, identifies the study area for each affected resource and describes the environment as it exists at this writing and forecasts its condition without new Federal coal leasing through the next 15 years.

Section 4, Environmental Impacts, is a resource by resource analysis of the impacts of new Federal coal leasing. Here the reader can find the detailed explanations for the impacts presented in Section 2. Thus if a reader wants to understand the impacts on raptors caused by the various alternatives, he may turn to the Wildlife portion of this section for an explanation.

Part II of the Study.

Each of the alternatives analyzed in the EIS is composed of a combination of mining tracts. These tracts were analyzed individually in documents called Site-Specific Analyses, which have been summarized in this document as Site-Specific Matrices. These matrices are supplied as a reference and show the basis of the EIS analysis. They should be used with caution since new data has become available during the preparation of the EIS. In addition, the alternative analysis is often more complex than a simple addition of the impacts noted in the matrices.

In those cases where methodology was too long or too complex to be easily presented in the body of the EIS, it has been placed in an appendix, which appears in Part II following the Site-Specific Matrices.

TOPIC AQRV for Flat Tops Wilderness Area.

REFERENCE #60 D. G. Fox and D. J. Murphy (1981). Air Quality, Oil Shale, and Wilderness: A Workshop to Help Identify and Protect Air Quality Related Values of the Flat Tops. (Draft Report). USDA. Forest Service. Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO.

ABSTRACT The specific group recommendations from this workshop are:

- Visibility: Proposed a long-term visibility monitoring program in the wilderness to measure current conditions, and those pollutants which have a potential to degrade visibility. Also proposed studies of wilderness users to identify the perception and significance of visibility impairment.

- Soil-Water: Proposed monitoring the sensitive, poorly buffered, high lakes (i.e., Surprise, Upper Island, and Shingle), for any changes in pH and nutrients. Additionally, the group proposed a modification to the current USFS Flat Tops water monitoring program and suggested long-term monitoring of precipitation quality, soil chemistry, and lake chemistry.

- Fish and Wildlife: This group outlined a process to aid the U.S. Forest Service to better identify sensitive receptors in the Flat Tops. Several sensitive indicator species to the expected pollutants are cutthroat trout, beaver, elk deer, white crowned sparrow, pika, ptarmigen, and bees. A long-term monitoring program of these species was identified.

- Vegetation: A two-stage monitoring program was suggested, the first stage utilizes the most sensitive plant species in the wilderness to alert the Federal Land Manager that air pollutants are reaching the wilderness in potentially significant quantities. The second stage would involve monitoring the viability of key species to the general Flat Tops ecosystem. The first stage indicators suggested were lichens and bryophytes to monitor sulfur dioxide (SO_2) and needle retention in spruce and fir to detect significant quantities of ozone (O_3).

- Modeling/climate: This group stressed the need for further research in deposition and dosage models. Since the Flat Tops Wilderness is the first high ground directly downwind from the oil shale area, pollutants released during mining and processing are likely to be deposited by both dry and wet (precipitation) mechanisms. Dosage models are needed to identify and quantify potential impacts on vegetation, soil, water, fish and wildlife. Availability of models will also aid in the conduct of monitoring programs by locating areas and times of greatest potential impact.

TOPIC

Ecosystem Model of the Effects of the Emerging Oil Shale Industry.

REFERENCE #61

J. G. Carter, et al. (1981). Monitoring Industrial Impacts: A Case Study of an Ecosystem Approach from the Oil Shale Industry. BN-SA-1361. Battelle, Pacific Northwest Laboratories, Richland, WA.

ABSTRACT

A description of the development of a monitoring program for detection and mitigation of effects of an oil shale industry. Seven years of environmental data and expected impacts were integrated using an ecosystem model as the organizing principal.

EPA Form 2360-4 (4-80)

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TOPIC Workshop on Acid Precipitation.

REFERENCE #62 U. S. DOE (1982). Workshop on the Source-Receptor Relationship in Acid Precipitation: Implications for Generation of Electric Power from Coal. Held at LaJolla, CA on 18-20 January 1982.

ABSTRACT

The observation of acid precipitation in various geographical areas has led to the development of a National Acid Precipitation Assessment Plan (NAPAP) that includes a broad research agenda for gaining an understanding of this complex phenomenon. This workshop was organized for the purpose of evaluating the research outlined in NAPAP to ascertain its relevance to policy decisions concerning the implementation of coal utilization technologies in the 1980's. This technical evaluation will provide support to individuals involved in planning Department of Energy research programs during the present decade.

The workshop, conducted over the three days of 18-20 January 1982, consisted of technical presentations rendered by experts currently working on the acid precipitation question and in allied fields. General areas discussed included:

Combustion Processes

Injection Dynamics

Transport Phenomena

Transformation Chemistry

Deposition Mechanisms

The workshop was not concerned with biological, sociological, etc. effects of acid precipitation. Discussions of individual presentations and roundtable discussions of subject areas were moderated by a panel of selected experts with appropriate qualifications, but who were not actively involved in research dealing with the specific subject matter.

TOPIC Precipitation Chemistry.

REFERENCE #63 J. M. Hales (Special Editor) 1982. "Special Issue: Precipitation Chemistry." Atmos. Environ. Vol. 16. pp. 1603-1796.

ABSTRACT The collection of articles in this *Atmospheric Environment* issue has been submitted as an additional step in fulfilling the pressing need to develop our mechanistic understanding of the phenomena of acid precipitation. The topics considered in this issue include the following:

- A statistical overview of the MAP3S/RAINE precipitation chemistry network.
- The chemistry of the atmospheric precipitation in the north central United States.
- The variation in chemical wet deposition with meteorological conditions.
- Trajectory analysis of MAP3S precipitation chemistry data at Ithaca, N.Y.
- Wet deposition variability as observed by MAP3S.
- A review and assessment of trace metals in atmospheric deposition.
- Factors influencing trace metals, sulfate and hydrogen ion concentrations in rain.
- SO_2 content in precipitation and its relationship with surface concentrations of SO_2 in the air.
- A scavenging model incorporating chemical kinetics.
- In-cloud and below-cloud scavenging of nitric acid vapor.
- In-cloud conversion rates of SO_2 to $SO_4^=$.
- Theoretical estimates of the scavenging coefficient for soluble aerosol particles as a function of precipitation type, rate and altitude.

- Average storm duration and seasonal precipitation rates for the northeast sector of the United States.

- A one-dimensional, time-variant model of precipitation scavenging.

- Particle deposiition to vegetative canopies.

J. HEALTH AND SOCIOECONOMIC IMPACTS

64. Brown, R.D. (Editor) (1979). Health and Environmental Effects of Oil Shale Technology. MTR-79W00136 (DOE/HEW/EPA-02). The MITRE Corp., McLean, VA.

65. Brown, R. D. (Editor) (1981). Health and Environmental Effects of Synthetic Fuel Technologies: Research Priorities. MTR-80W348. The MITRE Corp, McLean, VA.

66. Griest, W. G. and M. R. Guering (1981). Health Effects Investigation of Oil Shale Development. Ann Arbor Science Publ., Inc., Woburn, MA.

67. Holland, L. M. and C. G. Stafford (1981). The Los Alamos Integrated Oil Shale Health and Environmental Program: A Status Report. LA-8665-SR. Los Alamos Scientific Laboratory, Los Alamos, NM.

TOPIC

Health and Environmental Effects of Oil Shale Technology.

REFERENCE #64

R. D. Brown (Editor), 1979. Health and Environmental Effects of Oil Shale Technology. MTR-79W00136 (DOE/HEW/EPA-02). The MITRE Corp., McLean, VA.

ABSTRACT

This report is the result of a workshop which addressed the health and environmental effects of oil shale technology in Denver, Colorado, April 16-20, 1978 chaired by George Shepherd of the Department of Energy.

The purposes of this workshop were:

- to assemble biomedical and environmental scientists, representative of a broad range of disciplines, to address current development in oil shale technology
- to review and identify specific health and environmental issues and problems associated with the development and commercialization of oil shale technology
- to consider the research strategies required to address them and to identify the requisite research information needs, expressed via detailed task statements, for resolving the uncertainties of assessing the relevant impacts of oil shale technology.

Throughout the workshop, attendees participated in six panels: health effects; air quality; water quantity, quality, and aquatic ecology; terrestrial effects; ambient measuring and monitoring; and source characterization. This report contains a presentation of the highlights of the issues considered by the panels and the panel reports which contain specific information on environmental and health effects, information requirements, and detailed research statements. Lists of workshop participants, and support staff are provided in the Appendix.

TOPIC

Health and Environmental Effects of Synthetic Fuel Technologies.

REFERENCE #65

R. D. Brown (Editor), 1981. *Health and Environmental Effects of Synthetic Fuel Technologies: Research Priorities.* MTR-80W348. The MITRE Corp., McLean, VA.

ABSTRACT

This report is an assessment of the health and environmental effects research priorities related to coal gasification and liquefaction and oil shale development. It reflects the subjective judgments of well chosen research scientists in relevant disciplines. These scientists reviewed the results of workshops conducted in 1978 on coal gasification and liquefaction and oil shale, background information on related Federal research, and comments by relevant Federal agencies. The scientists prepared a listing of current research needs according to major areas of concern. These were categorized as to generic, region-specific, or process specific research. For the latter category, various scales of development were addressed for two exemplary processes: SRC (solvent refined coal) II and above ground oil shale retorting. Subjective judgments were used to prioritize the research tasks and assess the adequacy of current research. The activity of the scientists primarily was limited to the time period of three working sessions: health effects (September 8-10, 1980; Knoxville, Tennessee); air quality (August 12-14, 1980; Knoxville, Tennessee); and ecological effects (May 27-29, 1980, Oak Ridge, Tennessee). Following the working sessions, the scientists reviewed and commented on the material. The task force chairmen and their respective areas were: (1) Health Effects - James L. Epler, Cellular and Comparative Mutagenesis Section, Biology Division, Oak Ridge National Laboratory; (2) Air Quality - Terence H. Risby, Division of Environmental Chemistry, School of Hygiene and Public Health, Johns Hopkins University; and (3) Ecological Effects - Carl Gehrs, Advanced Fossil Energy Program, Environmental Science Division, Oak Ridge National Laboratory. The project coordinator was Richard D. Brown, The MITRE Corporation.

The information in this report is provided in a format which should be useful to a wide number of Federal, state, and local agencies and industry in establishing program plans and research priorities, and in identifying potential impacts which may

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require mitigation. The information also can be used by the basic research scientist as a guide to needed research related to the health and environmental effects of synthetic fuels development.

TOPIC Health Effects of Oil Shale Development.

REFERENCE #66 W. G. Griest and M. R. Guering (1981). Health Effects Investigation of Oil Shale Development. Ann Arbor Science Publ., Inc., Woburn, MA.

ABSTRACT Environmental and health issues must be addressed as an integral part of the development of synthetic fuels technology. To this end, experts from the government, military, and private business sectors are cooperating in an investigation of the potential health effects associated with the production and refining of shale oil into jet and diesel fuels. Groups of biologists, ecologists, and chemists in laboratories across the nation are involved in this multidisciplinary research effort.

This new book is a record of the findings to date, as presented at a symposium held in Gatlinburg, Tennessee, on June 23-24, 1980. The progress in this investigation, as summarized in this book, illustrates the success of this interagency matrix approach.

FEATURES:

- Matrix-approach investigation utilizing an especially diverse group of agencies, institutions, and perspectives.
- Focuses on a common set of samples from large-scale production and refining experience.
- Relies on exchanges of study materials and experimental results among various disciplines rather than on programmatic agency funding and direction.

For biologists, this book will be of interest as it concerns the bioassay system development and application from shale oil to synfuels. For chemists, comparative chemical analyses are included. Engineers will be interested in the chemical and physical properties of synfuels, and in the retorting and refining of shale oil. For all concerned with the environment, this look at one of the changes in the energy picture will prove a valuable necessity.

TOPIC Health and Environmental Concerns of Oil Shale Development.

REFERENCE #67 L. M. Holland and C. G. Stafford (1981). The Los Alamos Integrated Oil Shale Health and Environmental Program: A Status Report. LA-8665-SR. Los Alamos Scientific Laboratory, Los Alamos, NM.

ABSTRACT

This report summarizes the Los Alamos Scientific Laboratory (LASL) research activities addressing health and environmental concerns related to the developing U.S. oil shale industry. Individual projects are carried out by investigators in several groups within LASL's Life Sciences (LS), Health (H), and Chemistry-Materials Science (CMB) Divisions, with support from the Assistant Secretary for Environment of the United States Department of Energy (DOE).

The technical reports included in this document are organized on the basis of materials of concern rather than on laboratory organizational structure. Site- and technology-specific information is included in those instances where it is important to the understanding of the problem. Certain of the projects address more generic or fundamental questions common to most technologies, but each study, whether generic or applied, fits within the health and environmental concerns stated in the DOE Oil Shale Research Development and Demonstration (RD & D) Plan.

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K. FLOW AND DIFFUSION MODEL DEVELOPMENT AND MODEL PERFORMANCE

68. Fabrick, A. J. et al. (1977). Point Source Modeling: State-of-the-Art Assessment of Computer Simulation of Localized Air Pollution Emissions. Form and Substance, Inc. Westlake Village, CA.

69. Bass, A. et al. (1979). Development of Mesoscale Air Quality Simulation Models. Volume 1. Comparative Sensitivity Studies of Puff, Plume, and Grid Models for Long-Distance Dispersion. PB80-227580 National Technical Information Service, Springfield, VA.

70. Pielke, R. A. and R. T. McNider (1981). Impact of Topographic Circulations on the Transport and Dispersion of Air Pollutants. EPA-600/4-81-068. U.S. EPA, Research Triangle Park, NC.

71. Bencala, K. E. and J. H. Seinfeld (1979). "An Air Quality Model Performance Assessment Package." Atmos. Environ. 13, pp. 1181-1185.

72. Fox, D. G. (1981). "Judging Air Quality Model Performance: A Summary of the AMS Workshop on Dispersion Model Performance, Woods Hole, MA. 8-11 September 1980." Bull. Amer. Meteor. Soc. 62, pp. 599-609.

73. Yocke, M. A. and M. K. Liu (1978). Modeling Wind Distribution Over Complex Terrain. EPA-600/4-79-066, U.S. EPA, Las Vegas, NV.

74. Lavery, T. F. et al. (1982). EPA Complex Terrain Model Development First Milestone Report-1981. EPA-600/3-82-036, Environmental Research and Technology, Inc., Concord, MA.

75. Londergan, R. J. (1980). Protocol for Plume Model Validation, EA-1638 Research Project 1818 Final Report, TRC-Environmental Consultants, Inc., Wethersfield, CT.

76. Hillyer, M. J., S. D. Reynolds and P. M. Roth (1979). Procedures for Evaluating the Performance of Air Quality Simulation Models. EPA-450/4-79-033, Systems Applications, Inc., San Rafael, CA.

77. Hayes, S. R. (1979). Performance Measures and Standards for Air Quality Simulation Models. EPA-450/4-79-032, Systems Applications, Inc., San Rafael, CA.

78. Bowne, N. E., R. J. Londergan, D. R. Murray and H. Borenstein (1982). Overview, Results and Conclusions for the EPRI Plume Model Validation Project: Plains Site. EA-3074 Research Project 1616. TRC Environmental Consultants, Inc., East Hartford, CT.

79. Hilst, G. R. 1978. Plume Model Validation. EPRI EA-917-SY Workshop WS-78-99. Electric Power Research Institute, Palo Alto, CA.

80. Doran, J. C. and T. W. Horst (1983). "Observations and Models of Simple Nocturnal Slope Flows." J. Atmos. Sci., 40(3), pp. 708-717.

81. Garrett, A. J. (1983). "Drainage Flow Predictions with a One-Dimensional Model Including Canopy, Soil and Radiation Parameterizations." J. Appl. Meteor., Vol. 22(1), pp. 79-91.

82. Yamada, T. (1981). "A Numerical Simulation of Nocturnal Drainage Flow." J. Meteor. Soc. of Japan, 59(1), pp. 108-122.

83. Sherman, C.A. (1978). "A Mass-Consistent Model for Wind Fields Over Complex Terrain." J. Appl. Meteor., 17(3), pp. 312-319.

84. Lange, R. (1978). "ADPIC-A Three-Dimensional Particle-in-Cell Model for the Disposal of Atmospheric Pollutants and its Comparison to Regional Tracer Studies." J. Appl. Meteor., 17(3), pp. 320-329.

85. Lange, R. (1981). Modeling a Multiple Tracer Release Experiment During Nocturnal Drainage Flow in Complex Terrain. UCRL-85724 Preprint, Lawrence Livermore Laboratory, Livermore, CA.

86. Rao, K. S. and H. F. Snodgrass (1981). "A Nonstationary Nocturnal Drainage Flow Model." Bound. Layer Meteor., 20(3), pp. 309-320.

87. Childs, J. E. and W. E. Marlatt (1981). The Topographic Air Pollution Analysis System (TAPAS) - A Guide to the System Software Vols. 1 and 2. Department of Earth Resources, Colorado State University, Ft. Collins, Co.

88. Bader, D. C. and T. B. McKee (1983). "Dynamical Model Simulation of the Morning Boundary Layer Development in Deep Mountain Valleys." J. Climate and Appl. Meteor., 22(3): 341-351.

TOPIC Survey on Point Source Modeling.

REFERENCE #68 A. J. Fabrick, et al. (1977). Point Source Modeling: State-of-the-Art Assessment of Computer Simulation of Localized Air Pollution Emissions. Form and Substance, Inc., Westlake Village, CA.

ABSTRACT This report provides the results of a study of the comparative attributes of air pollution point source submodels. Submodels were tested against four data bases as well as against analytic solutions. The submodels that were determined to offer the greatest potential were assembled into two distinct models: a generalized Gaussian model, GEM (Gaussian Evaluation Model); and a finite difference model, IMPACT (Integrated Model for Plumes and Atmospherics in Complex Terrain). These final models were then evaluated using actual data taken from four field tests. GEM permits the user to specify options for each of the major parameters. The parameters that were evaluated include horizontal and vertical dispersion, standard deviations, plume rise, and various treatments of terrain and mixing layers. A useful extension of GEM was developed to automatically calculate concentrations over an array of receptors; this model is GEMGAR (GEM with Grided Array of Receptors). IMPACT was developed from the best state-of-the-art modules for wind field, diffusivity field, plume rise, pollutant transport, and chemistry. Field data employed for validation came from the NOAA program in Garfield, Utah; from the ARB programs at three California power plants; and from the Southern California Edison program at Ormond Beach in Ventura County, California. The relative precision, realism, and generality of each model were evaluated.

TOPIC Mesoscale Air Quality Simulation Models.

REFERENCE #69 A. Bass, et al. (1979). Development of Mesoscale Air Quality Simulation Models. Volume 1. Comparative Sensitivity Studies of Puff, Plume, and Grid Models for Long-Distance Dispersion. PB80-227580 NTIS, Springfield, VA.

ABSTRACT This report, Volume 1 in a series entitled 'Development of Mesoscale Air Quality Simulation Models', provides detailed comparisons and sensitivity analyses of three candidate models, MESOPLUME, MESOPUFF, and MESOGRID. This was not a validation study; there was no suitable regional air quality data base for the Four Corners area. Rather, the models have been evaluated by analyzing: model response to varying mesoscale flow regimes; model sensitivity to systematic variations in meteorological and model design parameters; and model accuracy versus computational requirements and cost.

Characteristics of the three models are:

- MESOPLUME, a mesoscale variable-trajectory Gaussian "plume-segment" model, adapted from the approach taken in the STRAM model (Hales et al. 1977);
- MESOPUFF, a mesoscale variable-trajectory Gaussian "puff" superposition model, adapted from the approach taken in the MESODIF model (Start and Wendell 1974);
- MESOGRID, a mesoscale Eulerian grid model based on the method of moments approach taken in the SULFA3D model (Egan et al. 1976).

Brief technical synopses of each of the three models are contained in Appendices A, B, and C, respectively; for additional information the individual model User's Guide (companion reports, Volumes 2-4) can be consulted: Benkley and Bass (1979a) for MESOPLUME, Benkley and Bass (1979b) for MESOPUFF, and Morris et al. (1979) for MESOGRID.

MESOPLUME AND MESOPUFF are variable-trajectory plume models: that is, they describe a continuous plume by the transport and dispersion of fluid elements (plume segments or puffs) in a continuously deformable windfield - see Figures 1-2 and 1-3. Variable-trajectory models of Gaussian type are natural extensions of the familiar straight-line Gaussian modeling approach (as described by Turner 1970), extensions that take into account the often-important variability of plume trajectories, especially over regional transport scales.

TOPIC A Mesoscale Model for Slope Flows and Mountain-Plain Circulations.

REFERENCE # 70 Pielke, R. A. and R. T. McNider (1981). Impact of Topographic Circulations on the Transport and Dispersion of Air Pollutants. EPA-600/4-81-068. U.S. EPA, Research Triangle Park, NC.

ABSTRACT

A numerical mesoscale model is utilized to examine slope flows and the classic mountain-plain circulation described by early investigators. Special emphasis is given to turbulent parameterization in the stable boundary layer and the unique characteristics of turbulent mixing in the slope flows. Tests of the first order turbulent parameterization used in the numerical model verified against data from the Wangara experiment showed a simpler parameterization can simulate the mean boundary layer structure as well as more complex higher order schemes. Additional tests for the Great Plains indicated terrain and boundary layer processes are sufficient to reproduce the strong low level jets observed in the area.

Simplified subsets of the equations for uniform slopes were solved analytically to elucidate the role of stratification in reducing slope flow strength and to examine oscillatory behavior of the slope flows. The numerical simulations for idealized valley-plain configurations produced results consistent with observations such as shallow sidewall flows, the pooling of cool air in the valley, and a deep mountain flow out of the valley.

A Lagrangian particle model, operating in the terrain following coordinate system of the mesoscale model, was developed to examine pollutant transport in the modeled circulations. To evaluate turbulent dispersion, a Markov statistical process dependent upon higher order turbulence parameters was used. Higher order turbulence parameters needed for the statistical model were directly computed from the numerical model. Results of dispersion tests in the modeled slope flows showed enhanced vertical dispersion in the slope flows compared to flow over a flat boundary and, importantly, that normal surface scaling parameters for pollutant dispersion such as friction velocity were inappropriate for the slope flows.

TOPIC Assessment of Performance of Air Quality Models.

REFERENCE #71 K. E. Bencala and J. H. Seinfeld (1979). "An Air Quality Model Performance Assessment Package." Atmos. Environ. 13. pp. 1181-1185.

ABSTRACT Methods for evaluating the performance of air quality models through comparison of observed and predicted concentrations are summarized and categorized. The comparisons are based on techniques for analyzing residuals, trends, and common air quality indices. The techniques have been incorporated into a computational package for the automatic assessment of model performance.

TOPIC Performance Criteria for Air Quality Models.

REFERENCE #72 D. G. Fox (1981). "Judging Air Quality Model Performance: A summary of the AMS Workshop on Dispersion Model Performance, Woods Hole, MA. 8-11 September 1980." Bulletin Amer. Meteor. Soc. 62. pp. 599-609.

ABSTRACT

Under the direction of the AMS Steering Committee for the EPA Cooperative Agreement on air quality modeling, a small group of scientists was convened to review and recommend procedures to evaluate the performance of air quality models. Particular attention was paid to the operational use of models in regulatory settings.

A number of general recommendations resulted from the workshop. The usefulness of models to aid decision makers in air quality management was reiterated. Concerns about the absolute, rather than the statistical, nature of air quality standards were raised, with a recommendation to reformulate standards accordingly. Model performance evaluation was suggested on the basis of differences between observed and predicted concentrations. The bias (average), the variance (noise), and the gross variability (gross error) of such differences were the recommended performance measures. In addition, correlation measures calculated in time, space, and jointly between observation and predictions were recommended. These measures and suggestions on how to apply them are outlined. Some qualification on the use of these measures for application to point sources using limited data sets was made.

The workshop did not recommend any specific numerical standards for acceptable model performance; there was insufficient information to do this. Rather, considerations for evaluating model performance using statistically constructed confidence intervals and comparison against EPA's currently used models were suggested.

Finally, areas in need of further research were identified. These include development and description of performance measures; application, especially to point source models; analysis of meteorological and air quality data, both existing and newly developed; and evaluation of diffusion modeling techniques.

TOPIC: Modeling Wind Fields - Three Dimensional Model

REFERENCE #73: Yocke, M. A. and M. K. Liu (1978). Modeling Wind Distribution Over Complex Terrain. EPA-600/7-49-066, Systems Applications, Inc., San Rafael, CA.

ABSTRACT

Accurate determination of wind fields is a prerequisite for successful air quality modeling. Thus, there is an increasing demand for objective techniques for analyzing and predicting wind distributions, particularly over rugged terrain, where the wind patterns are not only more complex, but also more difficult to characterize experimentally. This report describes the development of a three-dimensional wind model for rugged terrain based on mass continuity. The model is composed of several horizontal layers of variable thicknesses. For each layer, a Poisson equation is written with the wind convergence as the forcing function. Many types of wind perturbations over rugged terrain are considered in this model, including diversion of the flow due to topographic effects, modification of wind profiles due to frictional effects in the planetary boundary layer, convergence of the flow due to urban heat island effects, and mountain and valley winds due to thermal effects. Wind data collected during a comprehensive field measurement program at Phoenix, Arizona, were used to test the model. The model was shown both qualitatively and quantitatively to perform reasonably well in the application to Phoenix, and its utility was demonstrated by the relatively modest computing and data requirements in this application.

TOPIC

Complex Terrain Model Development

REFERENCE #74

T. F. Lavery, A. Bass, D. G. Strimaitis, A. Venkatram, B. R. Greene, P. J. Drivas and B. A. Egan (1982). EPA Complex Terrain Model Development First Milestone Report-1981. EPA-600/3-82-036 Environmental Research and Technology, Inc., Concord, MA.

ABSTRACT

The U.S. Environmental Protection Agency (EPA) is sponsoring the Complex Terrain Model Development (CTMD), a multi-year integrated program to develop and validate practical plume models of known reliability and accuracy for simulating 1-hour average ground-level concentrations downwind of elevated sources during stable atmospheric conditions in complex terrain. The first major component of the CTMD was a field program conducted during the fall of 1980 at Cinder Cone Butte (CCB), a roughly axisymmetric, isolated 100-meter hill located in the broad Snake River Basin near Boise, Idaho. The field program consisted of ten flow visualization experiments and 18 multi-hour tracer gas experiments conducted during stable flow conditions.

The data base compiled at CCB includes the following components:

- Source information: emission rates, locations, and heights of SF$_6$, CF$_3$Br, and oil-fog releases.
- Meteorological information: descriptions of the undisturbed mesoscale valley flow in the vicinity of CCB as well as information on flow and dispersion on and over CCB itself.
- Hill surface tracer gas concentrations: data from more than 14,000 individual bag samples collected over the 18 days of experiments from as many as 80 sampler locations in a given experiment.
- Lidar data: characterizing the plume trajectory and plume spread upwind and over CCB.
- Photographic data: still photographs taken from fixed locations on and around CCB, aerial photographs taken from an aircraft flying overhead, and 16 mm movies and videotapes.

This report presents an overview of the CCB experiment and the results of the modeling analyses completed through June 1, 1980. The objectives of the model analyses are to develop and evaluate new models using the CCB data base and to compare their performance to the following current complex terrain dispersion models:

- the EPA Valley model worst-case screening algorithm, widely used in regulatory practice to screen elevated sources in complex terrain;

- COMPLEX I and COMPLEX II, two new proposed complex terrain screening models issued by EPA for public testing and evaluation; and
- PFM, a potential flow model for turbulent dispersion of plumes in the presence of simple terrain features.

For these comparisons, 45 case study hours were selected from the 18 field experiment days. (The PFM model comparisons were made with about half of these case study hours).

Two new modeling approaches suggested by the experimental evidence have been formulated and tested. One new model (called the Impingement model) is used to simulate ground-level concentrations in strongly stable flows in which plumes go horizontally around the side of CCB; another new model (called the Neutral model) simulates slightly stable or neutral flows in which plumes rise over CCB. It must be emphasized, though, that these new models--which thus far represent only a modest level of effort-are tentative first steps toward the goal of practical, reliable complex terrain models. They are not the desired end results and are in no way identified for routine application at this time.

All models were evaluated by comparing 1-hour average observed concentrations with 1-hour average calculated concentrations. The results are encouraging: the two preliminary models appear to simulate maximum concentrations and spatial concentration patterns more realistically than the current models.

This report was submitted in partial fulfillment of Contract 68-02-3421 by Environmental Research & Technology, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 26, 1980 to June 1, 1981, and work was completed as of June 1, 1981.

TOPIC Plume Model Validation

Reference #75 Londergan, R. J. (1980). Protocol for Plume Model Validation. EA-1638 Research Project 1818, Final Report, TRC-Environmental Consultants, Inc., Wethersfield, CT.

Abstract

A procedure has been formulated for evaluating the performance of dispersion models used for predicting the short-term air quality impact of buoyant, elevated plumes. This procedure is proposed for use with the measurements acquired by the Plume Model Validation Program sponsored by the Electric Power Research Institute. The characteristics of the concentration pattern that plume models predict and which are useful for regulatory applications are the magnitude and location of the maximum concentration, the magnitude and location of the maximum concentration at a given distance, and pattern measures of ground-level concentration. The desired model performance attributes are absence of bias, absence of gross error, absence of correlation between residuals and observed values, and absence of correlation between residuals and exogenous variables. A methodology for testing for these attributes is proposed. The methodology combines a detailed examination of the magnitude and spatial pattern of ambient concentrations for selected events together with an analysis of the accumulated time history of concentrations over an extended period at a listed number of fixed locations.

TOPIC Evaluating Air Quality Simulation Models

REFERENCE #76 Hillyer, M. J., S. D. Reynolds and P. M. Roth (1979). Procedures for Evaluating the Performance of Air Quality Simulation Models. EPA-450/4-79-033, Systems Applications Inc., San Rafael, CA.

ABSTRACT

This report discusses the development of evaluation procedures for both short-term and long-term models, for both area-wide and site-specific applications. In a companion study under the same work assignment, model performance measures and standards are being examined to aid in assessing the relative accuracy and usability of any model for various applications.

The objective of this study is to lay the groundwork for a set of guidelines that can be implemented to aid in assessing performance characteristics of air quality models. Some of the topics investigated are:

- Reviewed previous model evaluation studies.
- Developed a general procedural framework for performing an evaluation study.
- Provided specific guidance, to the extent possible, with respect to the work required in each step of the performance evaluation procedure.
- Examined the role appropriate organizations should play in overseeing model evaluation studies.
- Identified gaps in present knowledge that limited our ability to provide more detailed guidance in this report, and presented recommendations for further work that will help to fill those gaps.

TOPIC Evaluation of Air Quality Simulation Models

REFERENCE #77 Hayes, S. R. (1979). Performance Measures and Standards for Air Quality Simulation Models. EPA-450/4-79-032, System Applications, Inc., San Rafael, CA.

ABSTRACT

Currently there are no standardized guidelines for evaluating the performance of air quality simulation models. In this report we develop a conceptual framework for objectively evaluating model performance. We define five attributes of a well-behaving model: accuracy of the peak prediction, absence of systematic bias, lack of gross error, temporal correlation, and spatial alignment. The relative importance of these attributes is shown to depend on the issue being addressed and the pollutant being considered. Acceptability of model behavior is determined by calculating several performance "measures" and comparing their values with specific "standards." Failure to demonstrate a particular attribute may or may not cause a model to be rejected, depending on the issue and pollutant.

Comprehensive background material is presented on the elements of the performance evaluation problem: the types of issues to be addressed, the classes of models to be used along with the applications for which they are suited, and the categories of performance measures available for consideration. Also, specific rationales are developed on which performance standards could be based. Guidance on the interpretation of performance measure values is provided by means of an example using a large, grid-based air quality model.

TOPIC

Plume Model Validation

REFERENCE #78

Bowne, N. E., R. J. Londergan, D. R. Murray and H. Borenstein (1982). Overview, Results and Conclusions for the EPRI Plume Model Validation Project: Plains Site. EA-3074 Research Project 1616, TRC Environmental Consultants, Inc., East Hartford, CT

ABSTRACT

The EPRI Plume Model Validation (PMV) Project is designed to provide the data bases and analyses for rigorous operational and scientific validation of plume models. The behavior and fate of buoyant plumes emitted from tall stacks are the foci of attention. A network of 200 tracer samplers, 28 air quality samplers, 2 aircrafts; 2 remote-sensing devices, and a full compliment of upper air and surface meteorological sensors were used to acquire data on plume behavior and ground-level concentrations in the vicinity of an isolated power plant located in the plains of central Illinois.

The present report is intended as an overview of the project and a summary of the results and conclusions. Four Gaussian models, commonly used for operational and regulatory purposes, and two numerical simulation models with first-order closure were tested against measured ground-level plume concentrations acquired during two spring and one summer season. Objective validation protocols and statistical methodologies developed for PMV were employed in these tests of model performance.

The results of these validation tests are described in this report. The major results can be summarized as follows:

1. Buoyant plumes emitted from tall stacks produce ground-level concentration patterns which differ from classical plume model predictions in significant ways:
   - The distribution of observed ground-level concentration was not matched by the predicted distribution.
   - While the maximum 1-hour concentration was predicted reasonably well, the 3-hour and 24-hour observed maxima were higher than predicted.
   - In view of the model's inability to estimate peak concentrations at the right place or for the right conditions, any match between peak observed and predicted values does not appear to derive from a correct description of the physics of plume disperison.

- The distribution of observed highest concentrations as a function of distance was flat from 3 to 30 kilometers. The model predicted highest concentrations decline steadily from 1 to 30 kilometers.
- Observed maximum concentrations were not a function of stability. The model predicted maximum occurred with Class A or B stability.

2. Gaussian predicted and observed concentrations were compared at the same time and location. Correlation coefficients indicated that the models exhibited no skill.

3. One of the first-order closure models was capable of predicting maximum concentrations with some skill, but the distribution of predicted concentrations did not match those observed.

4. Analyses of the components of the models indicated bias in several areas:

   - Observed plume width at the ground was greater than predicted.
   - Observed plume rise was less than predicted.
   - Observed wind speed profiles were different from those assumed in the models.

TOPIC

Plume Model Validation

REFERENCE #79

Hilst, G. R. (1978). Plume Model Validation. EPRI EA-917-SY Workshop WS-78-99, Electric Power Research Institute, Palo Alto, CA

ABSTRACT

The Electric Power Research Institute (EPRI) presents in this document an extensive planning study to determine the most appropriate development of a plume model validation protocol and, where necessary, an experimental program to provide reference data for model validations. This report summarizes the findings of these studies and outlines the recommended project structure for plume model validation.

TOPIC Nocturnal Slope Flow Model-Two-Dimensional

REFERENCE #80 Doran, J. C. and T. W. Horst (1983). "Observations and Models of Simple Nocturnal Slope Flows." J. Atmos. Sci. 40(3), pp. 708-717.

ABSTRACT Measurements of simple nocturnal slope winds were taken on Rattlesnake Mountain, a nearly ideal two-dimensional ridge. Tower and tethered balloon instrumentation allowed the determination of the wind and temperature characteristics of the katabatic layer as well as the ambient conditions. Two case studies were chosen; these were marked by well-defined surface-based temperature inversions and a low-level maximum in the downslope wind component. The downslope development of the slope flow could be determined from the tower measurements, and showed a progressive deepening of the katabatic layer. Hydraulic models developed by Manins and Sawford (1979a) and Briggs (1981) gave useful estimates of drainage layer depths, but were not otherwise applicable. A simple numerical model that relates the eddy diffusivity to the local turbulent kinetic energy was found to give good agreement with the observed wind and temperature profiles of the slope flows.

TOPIC	Drainage Flow Prediction-One-Dimensional Model
REFERENCE #81	Garrett, A. J. (1983). "Drainage Flow Prediction with a One-Dimensional Model Including Canopy, Soil and Radiation Parameterizations", J. Appl. Meteor., 22(1), pp. 79-91.
ABSTRACT	A mathematical model for simulation of winds over mountain slopes was developed and tested with observations from Australia and the western United States. The model computes profiles of wind and temperature normal to the slope. The model also computes soil heat fluxes, the mechanical and radiative effects of trees, terrestrial radiation fluxes and their modification by clouds, and turbulent heat and momentum fluxes. All variables are integrated over a slope of specified length and steepness. Comparison of available observations to simulated wind profiles showed general agreement, with the best agreement at sites on uniform slopes, and poorest agreement in complex terrain. The model is sensitive to variations in cloud height, forest coverage, slope parameters, and ambient winds and temperatures. This sensitivity implies that accurate simulations of drainage winds by multidimensional models will require inclusion of the same external parameters.

TOPIC — Simulation of Drainage Flow-Three-Dimensional Model

REFERENCE #82 — Yamada, T. (1981). "A Numerical Simulation of Nocturnal Drainage Flow," J. Meteor. Soc. of Japan, 59(1), pp. 108-122.

ABSTRACT

A three-dimensional mesoscale atmospheric model, previously used to simulate airflow over cooling ponds and hypothetical, simplified mountains, has been modified to simulate development of nocturnal drainage flow in realistic terrain, part of the California Geysers area. Turbulent fluxes appearing in the governing equations for mean variables are computed from simplified second-moment turbulence-closure equations where only a turbulence energy equation and a master-length scale equation are solved prognostically. Qualitative simulation of drainage flow, horizontal convergence in the valley, and resulting vertical motions are satisfactory. Simulated wind speeds near the surface are greater than observed values, possibly due to inadequate resolution of observations or to a lack of consideration of the drag associated with canopy flow.

TOPIC — Mass-Consistent Modeling of Wind Fields

REFERENCE #83 — Sherman, C. A. (1978). "A Mass-Consistent Model for Wind Fields Over Complex Terrain." J. Appl. Meteor., 17(3), pp. 312-319.

ABSTRACT — An adjustment model was developed to provide a pollutant transport model with input wind fields that are mass-consistent, three-dimensional, and also are representative of the available meteorological measurements. Interpolated three-dimensional mean winds were adjusted in a weighted least-squares sense to satisfy the continuity equation within the volume specified. The upper and lateral boundaries above topography were assumed to be open air and thus allowed mass flow through the boundaries. The bottom boundary was determined by the topographic elevations of the area being studied. The topographic boundary was assumed to be solid.

TOPIC Three-Dimensional Cartesian Particle-Diffusion Model

REFERENCE #84 Lange, R. (1978). "ADPIC-A Three-Dimensional Particle-in-Cell Model for the Dispersal of Atmospheric Pollutants and its Comparison to Regional Tracer Studies." J. Appl. Meteor., 17(3), pp. 320-329.

ABSTRACT A hybrid Lagrangian-Eulerian atmospheric transport-diffusion model was developed to calculate the three-dimensional distribution of atmospheric pollutants in transient-region flow fields. This Atmospheric Diffusion Particle-in-Cell (ADPIC) code was validated against several existing closed-form analytical solutions including a puff release in steady, unidirectional shear flow, and a puff release with scale-dependent horizontal and vertical eddy diffusion coefficients. These tests showed that the ADPIC results were within a 5% error when compared to the analytic solutions. Regional (100 km) tracer studies at the National Reactor Test Station Idaho Falls, Idaho, and at the Savannah River Laboratory, Aiken, SC, were also used to compare the code against field measurements.

TOPIC Modeling Multiple Tracer Releases in Complex Terrain

REFERENCE #85 Lange, R. (1981). Modeling a Multiple Tracer Release Experiment During Nocturnal Drainage Flow in Complex Terrain. UCRL-85724 PREPRINT. Lawrence Livermore Laboratory, Livermore, CA.

ABSTRACT The complex conditions posed by very localized winds and turbulence, rugged topography, variable surface roughness, strong vertical motions and gravity flow require a three-dimensional modeling approach to realistically simulate the dispersal of hydrogen sulfide injected into the atmosphere at the Geysers geothermal area. In this study the three-dimensional particle-in-cell numerical diffusion model ADPIC was used to simulate the transport and diffusion of two simultaneous, distinguishable fluorescent tracer releases into the nighttime drainage flow regimes of the Putah and Anderson Creeks in the Anderson Springs Valley during the night of July 24, 1979. Results were generally good although the model under-estimated the turbulent mixing.

TOPIC

Nonstationary Drainage Flow Model

REFERENCE #86

Rao, K. S. and H. F. Snodgrass (1981). "A Nonstationary Nocturnal Drainage Flow Model." Bound. Layer Meteor., 20(3), pp. 309-320.

ABSTRACT

The evolution and structure of the steady state of an idealized nocturnal drainage flow over a large uniformly-sloping surface are studied using a nonstationary model with a height-dependent eddy diffusivity profile and a specified surface cooling rate. The predicted mean velocity and temperature profiles are compared with Prandtl's stationary analytical solutions based on the assumption of a constant eddy diffusivity in the drainage layer. The effects of important physical parameters, such as the slope angle, surface cooling, atmospheric stability, and surface roughness, on the steady drainage flow are investigated.

TOPIC	Topographic Air Pollution Modeling
REFERENCE #87	Childs, J. E. and W. E. Marlatt (1981). The Topographic Air Pollution Analysis System (TAPAS)-A Guide to the System Software Vols. 1 and 2. Department of Earth Resources, Colorado State University.
ABSTRACT	The objective of this report is to summarize the documentation that has been created over the past decade on the TAPAS model and to demonstrate the current model design, implementation and function. The TAPAS model is a collection of 12 programs, most of which are designed to support facilities to the wind simulation models.

TOPIC

Multi-dimensional Cloud/Mesoscale Model-Two Dimensional Version

REFERENCE #88

Bader, D. C. and T. B. McKee (1983). "Dynamical Model Simulation of the Morning Boundary Layer Development in Deep Mountain Valleys." J. Climate and Appl. Meteor., 22(3): 341-351.

ABSTRACT

A dry, two-dimensional version of the Colorado State University Multi-dimensional Cloud/Mesoscale Model was used to study the cross-valley evolution of the wind and temperature structures in an idealized east-west oriented mountain valley. Two simulations were performed, one in which the valley was heated symmetrically and a second in which a mid-latitude heating distribution was imposed. Both runs were initiated identically with a stable layer filling the valley to ridgetop and a neutral layer above the ridge. A specified sinusoidal surface potential temperature flux function approximating the diurnal cycle forced the model at the lower boundary.

The results of the two simulations were remarkably similar. The model realistically reproduced the gross features found in actual valleys in both structure and timing. The simulated inversions were destroyed three and one-half hours after sunrise as a result of a neutral layer growing up from the surface meeting a descending inversion top. Slope winds with speeds of 3-5 m s^{-2} developed over both sidewalls two and one-half hours after sunrise. Both cases revealed the development of strongly stable pockets of air over the sidewalls which form when cold air advected upslope loses its buoyancy at higher elevations. These stable pockets temporarily block the slope flow and force transient cross-valley circulations to form which act to destabilize the valley boundary layer. Cross-valley mixing and gravity waves rapidly redistribute heat across the valley to prevent large potential temperature gradients from forming. As a result, even large differences in heating rates between opposing sidewalls do not result in significant cross-valley potential temperature differences. Organized cross-valley circulations and eddy motions enhance lateral mixing in the stable layer as well.

APPENDIX B

Bibliography
of
LITERATURE AND DATA APPLICABLE TO THE OIL SHALE AREA

The following tables summarize literature and data sources applicable to the oil shale region of Colorado, Wyoming and Utah. The references cited in these tables do not constitute a complete set of information, but merely reflect the efforts in collecting literature and data sources for the Green River Ambient Modeling Assessment Program. Table B-1 explains the entries used in Tables B-2a to B-2m. Tables B-2a to B-2m briefly characterize the material by subject matter, area of applicability, space scale, and time scale. The reference lists are given in numerical order for each subject category.

TABLE B-1

Explanation of the Entries in Tables B-2a to B-2m.

- Categories of Subject Matter

  a. Source
  b. Terrain
  c. Meteorology
  d. Chemistry
  e. Removal
  f. Visibility
  g. Effects (Air Quality Related Values)
  h. Instrument Systems
  i. Data Manipulation
  j. Oil Shale Processes & Resources
  k. Controls and Control Costs
  l. Social Impacts & Population Growth
  m. Literature Reviews & Abstracts

- Reference Number

  For each category of subject matter, references are listed as 1, 2, ..., n.

- Area of Applicability

  GE = Generic, work done elsewhere but applicable to the oil shale region.

RM = Work done in the Rocky Mountain West and applicable to the oil shale region.

OS = Work done for or in the oil shale region.

- Space Scales

MI = Microscale ($o \leq h \leq 2$ km).

LO = Local (2 km $\leq h \leq 20$ km).

ME = Mesoscale (20 km $\leq h \leq 200$ km).

RE = Regional (200 km $\leq h \leq 2000$ km) and/or Beyond Regional Scales ($h \geq 2000$ km).

h = horizontal scale.

- Time Scales

MI = t in terms of minutes.

HO = t in terms of hours.

DA = t in terms of days.

SE = t in terms of seasons, or in terms of longer periods.

t = time scale.

- Comments

a. Source

Background = Background pollutant sources for the oil shale region.

Manmade = Anthropogenic sources of pollutants.

Gases = Gaseous emissions.

Particles = Particulate emissions.

Field = Field data.

Lab = Laboratory data.

Model = Modeling information.

Theory = Theoretical information.

b. Terrain

Cover = Ground cover, surface roughness, and/or surface albedo topics.

Land Use = Land use information.

c. Meteorology

Wind = Wind speed and direction information.
Turbulence = Turbulence and diffusion information.
Temperature = Temperature and stability fields.
Precipitation = Rainfall and/or snowfall.
PBL = Planetary boundary layer.
Wakes = Flow around buildings.

d. Chemistry

Topics cover gaseous phase chemistry, photochemistry, gas-to-particle conversion, aerosol dynamics, and cloud condensation nuclei (CCN).

e. Removal

Topics include dry (Dry) removal of gases and particles, wet (Wet) removal of gases and particles, and some precipitation chemistry items.

f. Visibility

Topics include plume blight, and veiled and regional haze.

g. Effects

Topics include the acid precipitation effects on soils and water, and pollution effects on vegetation, fish and wildlife.

h. Instrument Systems

Topics include discussions on remote and in-situ systems, passive and active systems, and monitoring networks.

i. Data Manipulation

Topics include data processing, analysis and interpretation, and data reporting and archiving.

j. Oil Shale Processes and Resources

Topics include the character and extent of the resource, and the processes used to extract, retort and refine the resource.

k. Controls and Control Costs

Topics include controls and costs of controls for, or applicable to, the oil shale industry.

ℓ. Social Impacts & Population Growth

Topics include population sizes and growth potential in the oil shale region, social and economic implications of a growing oil shale industry, and human health effects of the industry.

m. Literature Reviews and Abstracts

References cited are literature reviews and/or collected abstracts of interest to the air quality investigator.

TABLE B-2a. SOURCE RELATED REFERENCES

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	1			X	X	X			X	X	X	X	Manmade, Gases, Particles
	2			X	X	X			X	X	X	X	Manmade, Gases, Particles
	3	X			X	X			X	X	X	X	Background, Gases, Particles
	4	X			X	X			X	X	X	X	Background, Gases, Particles
	5	X			X	X			X	X	X	X	Background, Gases, Particles
	6	X			X	X			X	X	X	X	Background, Gases, Particles
	7			X	X	X				X	X		Manmade, Gases, Particles
	8	X			X	X			X	X	X	X	Background, Gases, Particles
	9	X	X				X	X		X	X	X	SO_x Background, Statistical Models
	10	X	X		X	X	X		X	X	X	X	Symp. on Fugitive Emissions
	11	X				X				X	X	X	Particles From Diesels
	12		X			X	X			X	X		Wind-Blown Dust
	13		X			X	X	X			X	X	SO_2 From Smelters
	14	X			X				X	X	X	X	Emissions From Industrial Combustion
	15		X		X	X			X	X	X	X	Emissions From Utah Coal
	16		X		X	X			X	X	X	X	Wood-Stove Emissions
	17			X	X	X				X	X		H_2S From a Retort (model, lab)
	18	X			X	X				X	X	X	Emissions From Coal-Fired Power Plant
	19	X			X	X			X	X			Nitric Oxide in Power Plant Emissions Formation
	20			X	X	X				X	X	X	Analysis of C-a Retort Samples
	21	X			X	X			X	X			Emissions From Vehicles (research project)
	22		X		X	X			X	X			CO Emissions From Vehicles in Mountains (research project)
	23	X			X	X			X	X			Vehicle Emissions (research project)

(continued)

TABLE B-2a. (continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	24	X			X	X			X	X			Odors From Diesels (research project)
	25	X			X	X			X	X			Emissions From Advanced Technology Engines (research project)
	26	X			X	X			X	X			Emissions From Methanol-Gasoline Engines (research project)
	27	X			X	X			X	X	X		Transportation Source Inventories (research project)
	28	X			X	X			X	X			Diesel Particulate Emissions (research project)
	29	X			X	X			X	X			NO_x From Vehicles (research project)
	30	X			X	X			X	X			Emissions From Advanced Automotive Engines (research project)
	31	X			X	X			X	X			HC Emissions From Diesels (research project)
	32	X			X	X			X	X			Emissions From Diesel Automobiles (research project)
	33	X			X	X			X	X			Exhaust Organics From Vehicles (research project)
	34	X			X	X			X	X			Particulate Emissions From Vehicles (research project)
	35	X			X	X			X	X			Particulate Emissions From a Diesel Car (research project)
	36	X			X	X			X	X			Composition of Particles From Vehicles
	37	X			X	X			X	X			Diesel Emissions (research project)

(continued)

TABLE B-2a. (continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	38	X			X	X			X	X			Freon and Asbestos From Vehicles (research project)
	39	X			X	X			X	X			Diesel Vehicle Emissions (research project)
	40	X			X	X			X	X			Characterization of Diesel Exhaust (research project)
	41	X			X	X			X	X			Organics From Mobile Sources (research project)
	42	X			X	X			X	X			Emissions From Advanced Automotive Engines (research project)
	43	X			X	X			X	X			Emissions From Light Diesel Trucks (research project)
	44	X			X	X			X	X			Diesel Engine Emissions (research project)
	45	X	X			X	X	X		X	X		Impacts of Coal Conversion (background)
	46	X	X					X				X	Effects of CO_2 on Climate
	47	X	X					X				X	Inventory of U.S. Power Plants
	48	X	X			X	X	X			X	X	MAP3S/RAINE Emission Inventory
	49	X			X	X					X	X	Trace Elements From Power Plants
	50	X			X	X	X				X	X	Trace Elements From Power Plants
	51		X			X	X	X			X	X	SO_2 From Nonferrous Smelters
	52	X	X		X	X				X	X		Residental Wood Combustion Emission
	53	X			X	X			X	X			Wind Errosion Threshold Velocities
	54	X			X	X				X	X		Trace Metal Particulate Emissions

(continued)

TABLE B-2a. (continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	55	X			X	X	X			X	X		Trace Elements From Coal Combustion
	56	X				X	X			X	X		Toxic Elements and Trace Metals
	57	X			X	X					X	X	Hg Accumulation Around Power Plants
	58	X			X	X				X	X	X	Sulfur Flux From Biogenic Sources
	59	X			X	X				X	X		Natural Organic Sources
	60	X			X	X				X	X	X	Air Particulate Source Apportionment
	61	X			X	X				X	X	X	Review of Organic Compounds in the Atmosphere
	62	X				X	X			X	X		Particles and Gases From Forest Fires
	63	X			X	X				X	X	X	Emissions From Petroleum Refineries
	64	X			X	X				X	X	X	Emission From Petroleum Refineries
	65	X			X	X			X	X			NO_x National Emission Inventory
	66			X	X				X	X			Oil Shale Retort Effluents
	67		X		X	X			X	X	X		Emissions From Tar Sand Processes
	68			X	X	X			X	X	X	X	Oil Shale Emissions Summary
	69	X		X				X				X	Global CO_2 Problems
	70	X		X				X				X	Global CO_2 Problems
	71	X	X		X	X				X	X		Residential Wood Combustion Emissions
	72	X			X	X			X	X	X	X	Survey of Fugitive Emission Factors

(continued)

TABLE B-2a. (continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	73			X	X	X					X	X	Variations in Ozone Concentration
	74		X		X	X				X	X		Fugitive Dusts From Coal Mines
	75			X	X	X				X	X	X	Potential Emissions From Oil Shale Facilities
	76	X		X	X	X				X	X	X	Oil Shale Emission Factors
	77			X	X	X					X	X	Oil Shale Emissions
	78	X	X				X	X			X	X	Emissions From Coal Facilities
	79	X	X				X	X			X	X	Emissions From Coal Facilities
	80	X	X				X	X			X	X	Particle Emissions From Wood Stoves
	81		X				X	X			X	X	Emissions From Power Plants
	82		X				X	X			X	X	Emissions From Power Plants
	83			X	X	X				X	X	X	Oil Shale Emissions
	84			X	X	X				X	X		Oil Shale Emissions (surface retorts)
	85		X				X	X			X	X	Emissions From Power Plants
	86	X	X				X	X			X	X	Emissions From Coal Conversion
	87	X		X	X	X				X	X		Emissions From Synthetic Combustion Fuel
	88	X		X	X	X				X	X		Soot Formation in Synfuels
	89	X		X	X	X				X	X		Soot Formation in Synfuels
	90		X		X	X				X	X		Underground Gasification of Coal
	91			X	X	X					X	X	Emissions From Spent Shale Piles
	92		X				X	X			X	X	Trace Elements From Coal Combustion
	93		X				X	X			X	X	Submicron Particles From Coal Combustion

(continued)

TABLE B-2a. (continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Source	94	X					X	X			X	X	Particles From Oil-Fired Boilers
	95	X			X	X			X	X	X		Modeling Fugitive Dust From Mines
	96	X			X	X			X	X	X		Source/Receptor Models
	97	X			X	X			X	X			Source/Receptor Models: Urban Highways
	98	X			X	X			X	X			Wind Speed versus TSP-Levels
	99	X			X	X			X	X	X	X	Symp. on Fugitive Emissions
	END	-	-	-	-	-	-	-	-	-	-	-	---

REFERENCES

a. Source

1. Brown, R. D. (Editor). Health and Environmental Effects of Oil Shale Technology. DOE/HEW/EPA-02 and MTR-79W00136. The Mitre Corp., McLean, VA. 1979.

2. Brown, R. D. Health and Environmental Effects of Synthetic Fuel Technologies: Research Priorities. MTR-80W348. The Mitre Corp., McLean, VA. 1981.

3. Brown, R. D. and A. Witter. Health and Environmental Effects of Coal Gasification and Liquefaction Technologies. DOE/HEW/EPA-03 and MTR-79W00137. The Mitre Corp., McLean, VA. 1979.

4. Brown, R. D. (Editor). Health Effects of Coal Technologies: Research Needs. DOE/HHS/EPA-05 and MTR-79W15902. The Mitre Corp., McLean, VA. 1980.

5. Muradaz, M. A., et al. Survey of Coal Technologies. MTR-79W0070. The Mitre Corp., McLean, VA. 1979.

6. Brown, R. D. (Editor). Environmental Effects of Coal Technologies: Research Needs. MTR-79W159-03. The Mitre Corp., McLean, VA. 1981.

7. Blair, J., et al. Environmental Research on a Modified in-Situ Oil Shale Process: A Progress Report from the Oil Shale Task Force. DOE/EV-0078. U. S. Dept. of Energy, Washington, D.C. 1980.

8. Brown, R. D. (Editor). Health and Environmental Effects of Oil and Gas Technologies: Research Needs. MTR-81W77. The Mitre Corp., McLean, VA. 1981.

9. Nochumson, D. H. Explaining Spatial Variation of Atmospheric Sulfur Oxides. Paper No. 77-50.3. Pres. at the 70th Annual Meeting of the Air Pollution Control Association. Held at Toronto, Canada on 20-24 June 1977.

10. Wibberley, C. Symposium on Fugitive Emissions Measurement and Control (4th) held at New Orleans, LA on May 28-30, 1980. EPA-600/9-80-041. U. S. EPA. Research Triangle Park, N.C. 1980.

11. Heiser, D. P. An Investigation of Future Ambient Diesel Particulate Levels Occurring in Large Scale Urban Areas. EPA-AA-SDSB-79-30. U. S. EPA. Ann Arbor, MI. 1979.

12. Record, F. A. and L. A. Baci. Evaluation of Contribution of Wind Blown Dust from the Desert to Levels of Particulate Matter in Desert Communities. EPA-4501-2-80-078. U. S. EPA. Research Triangle Park, N.C. 1980.

13. Mangeng, C. and R. Mead. Sulfur Dioxide Emissions from Primary Nonferrous Smelters in the Western United States. LA-8268-MS. Los Alamos Scientific Lab., Los Alamos, N.M. 1980.

14. Surprenant, N. F., _et al_. Emission Assessment of Conventional Stationary Combustion Systems: Volume V: Industrial Combustion Sources. EPA-600/7-81-003C. U. S. EPA , Research Triangle Park, N.C. 1981.

15. Doelling, H. H., _et al_. Coal Studies: Methane Content of Utah Coals: Observations on the Surryside Coal Zone: Chemical Analysis of Coal from the Blackhawk Formation, Wasatch Plateau Coal Field, Carbon, Emery, and Sevier Counties. Special Studies 49. Utah Geological and Mineral Survey, Salt Lake City, Utah. 1979.

16. Peters, J. A. and D. G. DeAngelis. High Altitude Testing of Residential Wood-Fired Combustion Equipment. EPA-600/2-81-127. U. S. EPA, Research Triangle Park, N.C. 1981.

17. Burnham, A. K., _et al_. H_2S Evolution from Colorado Oil Shale. UCRL-84066. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

18. Ondor, J. M. and A. H. Biermann. Physical and Chemical Characterization of Aerosol Emissions from Coal-Fired Power Plants. UCRL-82761. Lawrence Livermore National Laboratory, Livermore, CA. 1979.

19. Houser, T. and M. E. McCarville. Fundamentals of Nitric Oxide Formation in Fossil Fuel Combustion. Progress Report, March 29-June 28, 1980. FE-2018-17. Dept. of Chem., Univ. of Western Michigan, Kalamazoo, MI. 1980.

20. Oil Shale Retort Samples Analyzed. Physical Sciences Dept., Pacific Northwest Laboratory, Richland, WA. 1981.

21. Brach, P. Vehicle Operation, Fuel Consumption, and Emissions as Related to Highway Design and Operation. SSIE No. BI-157068. U. S. Dept. of Transportation, Federal Highway Admin., Washington, D.C. 1981.

22. Eberaneberhorst, R. & P. Ienz. CO Emissions from Passenger Cars on High Mountain Roads. SSIE No. BI-172185. Federal Ministry of Building & Technology, Vienna, Austria. 1981.

23. Griffin, R. Air Quality Considerations in Traffic Signaling Decisions. SSIE No. BI-192569. U. S. Dept. of Transportation, Washington, D.C. 1981.

24. Cernansky, N. P. Physical and Chemical Phenomena Responsible for Odor Formation in Diesel Engines. SSIE No. CD-285-3. U. S. National Science Foundation , Washington, D.C. 1981.

25. Horn, R. Exhaust Products from Alternate Fuels, and Advanced Technology Engines. SSIE No. ER-929-1. U. S. Dept. of Energy , Washington, D.C. 1981.

26. Adt, R. R. Methanol-Gasoline Blends Performance and Emissions Characterization Research. SSIE No. FD-737. U. S. Dept. of Energy , Washington, D.C. 1981.

27. Marmo, F. Transportation Energy Research (Air Quality Assessments). SSIE No. FE-547, U.S. Dept. of Transportation, Washington, D.C. 1981.

28. U. S. DOE. Diesel Particulate Emissions. SSIE. No. FJ-2408. U. S. Dept. of Energy , Washington, D.C. 1981.

29. Martin, S. F., et al. Characterization of Emissions from Prototype Motor Vehicles Designed for Low NO_x Emissions. SSIE No. GMA-3592-2. U. S. EPA , Research Triangle Park, N.C. 1981.

30. Hare, C. T. Characterization of Emissions from Advanced Automotive Power Plant Concepts. SSIE No. GMA-3755-3. U. S. EPA, Research Triangle Park, N.C. 1981.

31. French, C. C., et al. Development of a Methodology for the Determination of Diesel Total Hydrocarbon Emission Rates for Cyclic Driving Conditions. SSIE No. GMA-4885-1. U. S. EPA , Research Triangle Park, N.C. 1981.

32. Gibbs, R. E. and S. M. Byers. Fuel Economy and Emissions Performance of Diesel Automobiles. SSIE No. GMA-5198-2. U. S. EPA, Research Triangle Park, N.C. 1981.

33. Pellizzari, E. D.and M. D. Erickson. GC/MS Support for In-House Source Program. SSIE No. GMA-5804. U. S. EPA , Research Triangle Park, N.C. 1981.

34. Hare, C. T. Study of Particulate Emissions from Motor Vehicles - Report to Congress. SSIE No. GMA-6379. U. S. EPA, Research Triangle Park, N.C. 1981.

35. Peters, E. Study and Collect Particle Emissions from Turbocharged Rabbit Diesel. SSIE No. GMA-6755-1. U. S. EPA , Research Triangle Park, N.C. 1981.

36. Miller, J. L. Morphology and Composition of Particulates Emitted by Mobile Sources. SSIE No. ZMA-921-1. U. S. EPA , Research Triangle Park, N.C. 1981.

37. Bradow, R. L., et al. Diesel Emissions Research. SSIE No. ZMA-1836. U. S. EPA, Research Triangle Park, N.C. 1981

38. Bradow, R. Management of Research on Freon and Asbestos from Automobiles. SSIE No. ZMA-1957. U. S. EPA, Research Triangle Park, N.C. 1981.

39. Bradow, R. L. Management of Surveillance of In-Use Diesel Vehicles Research. SSIE No. ZMA-2012. U. S. EPA, Research Triangle Park, N.C. 1981.

40. Bradow, R. L. Management of the Chemical Characterization of Diesel Exhaust Research. SSIE No. ZMA-2013. U. S. EPA, Research Triangle Park, N.C. 1981.

41. Bradow, R. L. Management and In-House Research on Mobile Source Hydrocarbons Emissions Measurement. SSIE No. ZMA-2014. U. S. EPA, Research Triangle Park, N.C. 1981.

42. Bradow, R. L. Management and In-House Research on Emissions from Diesel Engines and Other Advanced Automotive Power Plants. SSIE No. ZMA-2015. U. S. EPA, Research Triangle Park, N.C. 1981.

43. Forrest, L. Environmental Impacts of Light Duty Vehicle Dieselization. SSIE No. FA-362. U. S. Dept. of Transportation, Washington, D.C. 1981.

44. Goodsen, E. Purdue Automotive Research. SSIE No. FE-546. U. S. Dept. of Transportation, Washington, D.C. 1981.

45. Kornegay, F. C. "Assessing the Air Quality Related Impacts of Coal Conversion Facilities." Environ. and Climatic Impact of Coal Utilization. Academic Press, New York, N.Y. 1980. pp. 541-550.

46. Emanuel, W. R., et al. "The Expanded Use of Fossil Fuels by the U. S. and the Global Carbon Dioxide Problem." J. Environ. Manage. 10. 1980. pp. 37-49.

47. U. S. DOE. Inventory of Power Plants in the United States. 1980 Annual DOE/EIA-0095(80). U. S. Dept. of Energy, Washington, D.C. 1981.

48. Benkovitz, C. M. MAP3S/RAINE Emissions Inventory Progress Report. BNL-51378. Brookhaven National Laboratory, Upton, N.Y. 1980.

49. Evans, D. W., et al. "Trace Element Inputs from a Coal Burning Power Plant to Adjacent Terrestrial and Aquatic Environments." APCA Journal. 30. 1980. pp. 567-573.

50. Struempler, A. W. "Trace Element Composition in Atmospheric Particulates During 1973 and the Summer of 1974 at Chadron, Neb." Environ. Sci. & Tech. 9. 1975. pp. 1164-1168.

51. Mangeng, C. and R. Mead. Sulfur Dioxide Emissions from Primary Nonferrous Smelters in the Western U.S. (Draft Report.) Los Alamos National Laboratory, Los Alamos, N.M. 1980.

52. Cooper, J. A. Environmental Impact of Residential Wood Combustion Emissions and Its Implications. Oregon Graduate School, Beaverton, Oregon. 1980.

53. Gillette, D. "Tests with a Portable Wind Tunnel for Determining Wind Erosion Threshold Velocities." Atmos. Environ. 12. 1978. pp. 2309-2313.

54. Jacko, R. B. and D. W. Neuendorf. "Trace Metal Particulate Emission Test Results from a Number of Industrial and Municipal Point Sources." APCA J. 27. 1977. pp. 989-994.

55. Lim, M. Y. Trace Elements from Coal Combustion - Atmospheric Emissions. ICTIS/TR05. IEA Coal Research, London England. 1979.

56. Miller, J. M. (Editor). The Potential Atmospheric Impact of Chemicals Released to the Environment: Proceedings of Four Workshops. EPA 560/5-80-001. U. S. EPA, Washington, D. C. 1981.

57. Crockett, A. B. and R. R. Kinnison. "Mercury Residues in Soil Around a Large Coal-Fired Power Plant." Environ. Sci. and Tech. 13. 1979. pp. 712-715.

58. Aneja, V. P., et al. "Emission Survey of Biogenic Sulfur Flux from Terrestrial Surfaces." APCA J. 31. 1981. pp. 256-258.

59. Dimitriades, B. "The Role of Natural Organics in Photochemical Air Pollution." APCA J. 31. 1981. pp. 229-235.

60. Cooper, J. A. and J. G. Watson, Jr. "Receptor Oriented Methods of Air Particulate Opportionment." APCA J. 30. 1980. pp. 1116-1125.

61. Lamb, S. I., et al. "Organic Compounds in Urban Atmospheres: A Review of Distribution, Collection and Analysis." APCA J. 30. 1980. pp. 1098-1115.

62. Radke, L. F., et al. "Airborne Studies of Particles and Gases from Forest Fires." APCA J. 28. 1978. pp. 31-34.

63. Wetherold, R. G., et al. Assessment of Atmospheric Emissions from Petroleum Refining: Volume 3, Appendix B. EPA-600/2-80-075c. U. S. EPA, Research Triangle Park, N.C. 1980.

64. Wetherold, R. G. Assessment of Atmospheric Emissions from Petroleum Refining: Volume 5. Appendix F. EPA-600/2-80-075e. U. S. EPA, Research Triangle Park, N.C. 1980.

65. Wolcott, M. NO_x National Emission Inventory Estimates. EPA-AA-TEB-80-19. U. S. EPA, Ann Arbor, MI. 1980.

66. Fruchter, J. S. and C. L. Wilkerson. "Characterization of Oil Shale Retort Effluents." Oil Shale, the Environmental Challenges. Colorado School of Mines Press, Golden, CO. 1981. pp. 31-55.

67. Skinner, Q. Environmental Survey-Tar Sands in-Situ Processing Research Program (Verral, Uintah County, Utah). DOE/LETC/IC-80/1. Rocky Mountain Institute for Energy and Environment. Univ. of Wyoming, Laramie, Wyoming. 1980.

68. Bates, E. R. and T. L. Thoem. Environmental Perspective on the Emerging Oil Shale Industry. EPA-600/2-80-205a. Cincinnati, Ohio: U. S. Environmental Protection Agency. 1980.

69. Moskowitz, P. D., et al. "The Global Carbon Dioxide Problem: Impacts of U. S. Synthetic Fuel and Coal-Fired Electricity Generating Plants." APCA J. 30. 1980. pp. 353-357.

70. Speth, G. (Editor). Global Energy Futures and the Global Carbon Dioxide Problem. Council on Environmental Quality, Washington, D.C. 1981.

71. Cooper, J. A. "Environmental Impact of Residential Wood Combustion Emissions and Its Implications." J. APCA. 30. 1980. pp. 855-861.

72. Griffiths, J. F. Literature Review of Fugitive Emissions Factors for Surface Mining Activities. AV-R-81/544. AeroVironment, Inc., Pasadena, CA, 1981.

73. Chan, M. W. and M. I. Smith. Long-term Variations in Ozone Measurements in a Remote Area in Northeastern Utah. No. 81-6.3. Pres. at 74th Annual Meeting of APCA, Philadelphia, PA, June 21-26, 1981.

74. Cook, F., et al. Project Summary-Fugitive Dust from Western Surface Coal Mines. EPA-600/PS7-80-158. U. S. Environmental Protection Agency, Cincinnati, OH, 1980.

75. U. S. Congress, Office of Technology Assessment. An Assessment of Oil Shale Technologies. U. S. Government Printing Office, Washington, D.C., 1980.

76. House, P. W. Technology Characterizations: Environmental Information Handbook. DOE/EV-0072, U. S. Department of Energy, Washington, D.C., 1980.

77. Thoem, T. L. "EPA and Oil Shale." Presented at the Outlook for Oil Shale, Brown Place Hotel, Denver, CO. June 19 & 20, 1980.

78. McNeil, T., et al. An Assessment of National Consequences of Increased Coal Utilization: Volume 1, Executive Summary. U. S. Dept. of Energy, Washington, D.C. 1978.

79. Surles, T., et al. An Assessment of National Consequences of Increased Coal Utilization: Volume 2. U. S. Dept. of Energy, Washington, D.C. 1978.

80. Allwine, K. J., Jr. Assessment of the Long-Range Transport of Residential Woodstove Fine Particulate Emissions for two Future United States Energy Scenarios. PNL-SA-9606. Pacific Northwest Laboratory, Richland, WA. 1981.

81. Burnham, J. B., et al. The Impact of Increased Coal Consumption on the Pacific Northwest. BNWL-RAP-21. Pacific Northwest Laboratory, Richland, WA. 1978.

82. Sandusky, W. F., et al. Long-Range Transport of Sulfur in the Western United States. PNL-RAP-26. Pacific Northwest Laboratory, Richland, WA. 1979.

83. Hessel, D. L. and G. Strasser. Draft Final Report: Western Oil Shale Development - A Technology Assessment. PNL-3830, Pacific Northwest Laboratory, Richland, WA. May 1981.

84. Oil Shale Surface Retorting: Environmental Characterization Information Report. Aerospace Corp.,Germantown, MD (USA). DOE/EP-0015. Jan. 1981.

85. Coal-Fired Power Plant (Western Coal): Environmental Characterization Information Report. Aerospace Corp.,Germantown, MD (USA). DOE/EP-0019. Jan. 1981.

86. Pollutants From Coal Conversion Processes. First progress report. September 1, 1980-February 28, 1981. North Carolina State Univ., Raleigh (USA). DOE/PC/30232-T1. 1981.

87. Tanzawa, T, R. H. Krech, W. T. Rawlins. Synthetic Fuel Combustion: Pollutant Formation. Soot Initiation Mechanisms in Burning Aromatics. Physical Sciences, Inc., Woburn, MA (USA). DOE/PC/30292-2. April 1981.

88. Olson, D. B. Soot Formation in Synfuels. First Quarterly Report, 19 September-31 December 1980. AeroChem Research Labs., Inc., Princeton, N.J. (USA). DOE/PC/30304-1. March 1981.

89. Haebig, J. E.and P. M. Goldberg. Effects of Components of Synfuels on Soot Formation. Gulf Science and Technology Co., Pittsburgh, PA (USA). DOE/PC/30307-3. August 1981.

90. Underground Gasification of Steeply Dipping Beds. Gulf Research and Development Co., Pittsburgh, PA (USA). DOE/ET/13108-T14. 1981.

91. Role of Spent Shale in Oil Shale Processing and the Management of Environmental Residues. Colorado School of Mines, Golden (USA). DOE/LETC/10020-1*. 15 Aug. 1980.

92. Environmental Assessment of Trace Elements from Coal Combustion in the Semi-Arid West. Los Alamos Scientific Lab.,NM (USA). LA-8660-MS*. Feb. 1981.

93. Pennucci, J., R. Greif, G. Parsons, F. Robben, P. Sherman. Submicron Particulates from Pulverized-Coal Combustion. Lawrence Berkeley Lab., CA (USA). LBL-12485. March 1981.

94. Piper, B. F., S. Hersh, D. J. Mormile. Particulate Emission Characteristics of Oil-Fired Utility Boilers. KVB, Inc. Elmsford, N.Y. (USA). EPRI-CS-1995. August 1981.

95. Winges, K. D. Development of an Air Quality Model for Mining Fugitive Dust." Paper #82-47.1. Presented at 75th Annual Meeting of APCA at New Orleans, LA. 20-25 June 1982.

96. Gordon, G. E. "Receptor Models". Environ. Sci. & Tech. 14. 1980. pp. 792-800.

97. Hopke, P. K., et al. "Multielement Characterization of Urban Roadway Dust." Environ. Sci. and Tech. 14. 1980. pp. 164-172.

98. Evans, J. S., et al. "A Study of the Relationship Between Wind Speed and Total Suspended Particulate Levels." APCA J. 31. 1981. pp. 395-397.

99. Wibberley, C. Symposium on Fugitive Emissions Measurement and Control (4th) held at New Orleans, LA on May 28-30, 1980. EPA-600/9-80-041. U. S. EPA, Research Triangle Park, N.C. 1980.

TABLE B-2b. REFERENCE ON TERRAIN--RELATED SUBJECTS

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Terrain	1		X	X		X	X	X				X	Cover, Land Use, Field
	2		X	X		X	X	X				X	Cover, Land Use, Field
	3		X	X		X	X	X				X	Cover, Land Use, Field
	4		X	X		X	X	X				X	Cover, Land Use, Field
	5		X	X		X	X	X				X	Cover, Land Use, Field
	6	X				X	X	X				X	Cover, Land Use, Field
	7	X				X	X	X				X	Remote Sensing of Terrain
	8			X	X	X	X					X	White River National Forest Map
	9			X	X	X						X	Flat Tops Wilderness Map
	10			X	X	X						X	Vegetation Map; Piceance Basin
	11			X	X	X	X					X	USGS Map Coverage of the Oil Shale Area
	12			X	X	X						X	Oil Shale Lease Site Maps
	13		X	X	X	X	X					X	Land Use Map of Colorado
	14		X	X	X	X	X					X	Land Use and Snow Depth Maps for Colorado
	15			X	X	X	X					X	Ground Cover Map of Wyoming
	16			X	X	X	X					X	Ground Cover Map of Wyoming
	17		X	X	X	X	X					X	Ground Cover Map of Utah
	18		X	X	X	X	X					X	Ground Cover Map of Utah
	19		X	X	X	X	X					X	Ground Cover Map of Colorado
	20			X	X	X						X	Ground Cover Map: Garfield County, Colorado
	21	X				X	X			X		X	Topographical Data From LANDSAT
	END	-	-	-	-	-	-	-	-	-	-	-	---

REFERENCES

b. Terrain

1. Heckathorn, B. R., et al. Green River Basin: Wyoming, Type IV, Cooperative River Basin Study, Forestry. M7-N-23596. U. S. Dept. of Ag., Soil Conservation Service, Portland, OR. 1976.

2. Keetch, M. R. Green River Basin: Wyoming, Type IV, Cooperative River Basin Study, Recreation. M7-N-23596. U. S. Dept. of Ag., Soil Conservation Service, Portland, OR. 1975.

3. Hanson, M. L., et al. Green River Basin: Wyoming, Type IV, Cooperative River Basin Study, Environmental Base Working Paper. M7-N-23596. U. S. Dept. of Ag., Soil Conservation Service, Portland, OR. 1978.

4. Heckathorn, B. R., et al. Green River Basin: Wyoming, Type IV, Cooperative River Basin Study, Base Resource. M7-N-23596. U. S. Dept. of Ag., Soil Conservation Service, Portland, OR. 1977.

5. Rintamaki, R. C. Green River Basin: Wyoming, Main Report, Cooperative River Basin Study. U. S. Dept. of Ag., Soil Conservation Service, Portland, OR. 1978.

6. Geo. Washington Univ. Digital Geographic Information Systems. Short Course, No. 708DC. George Washington University, Washington, D.C. 1982.

7. Geo. Washington Univ. Fundamentals of Remote Sensing for Terrain Analysis. Short Course, No. 730DC. George Washington University, Washington, D.C. 1982.

8. USDA. White River National Forest, Colorado: National Forest Visitors Map. U. S. D. A. Forest Service, Forest Supervisor, Glenwood Springs, CO. 1979.

9. USDA. Flat Tops Wilderness: National Forest Visitors Map. U. S. D. A. Forest Service, Forest Supervisor, Glenwood Springs, CO. 1979.

10. CSU. Vegetation Map: Piceance Basin and Roan Plateau, Colorado. Range Science Department, Colorado State University, Fort Collins, CO. 1973.

11. USGS. Ogden, Rock Springs, Rawlins, Salt Lake City, Vernal, Craig, Price, Grand Junction, Leadville, Salina, Moab, Montrose 1/250,000 Contour Maps, U. S. Geological Survey, Denver, CO. 1962-1977.

12. EDC. Utah and Colorado Oil Shale Site Contour Maps. Energy Development Consultants, Inc., Denver, CO. 1979.

13. USDA. Generalized Land Use Map of Colorado. U. S. D. A. Soil Conservation Service, Portland, OR. 1965.

14. Colorado. Maps: Existing Land Use (1973) and Snow Depth (1974) for Colorado. Colorado Land Use Commission, Denver, CO. 1974.

15. USDA. Generalized Aspect (Ground Cover Map) of the Green River Basin of Wyoming. U. S. D. A. Soil Conservation Service, Portland, OR. 1976.

16. USDA. Recreation Setting (Ground Cover Map) of the Green River Basin of Wyoming. U. S. D. A. Soil Conservation Service, Portland, OR. 1976.

17. USDA. Utah Map: Vegetative Types and Land Resource Areas. U. S. D. A. Soil Conservation Service, Portland, OR. 1977.

18. USDA. Utah Map: Irrigated and Dryland Farming Areas. U. S. D. A. Soil Conservation Service, Portland, OR. 1959.

19. USDA. Colorado Map: Natural Vegetation. U. S. D. A. Soil Conservation Service, Portland, OR. 1972.

20. USDA. Garfield County Colorado Map: Land Use and Natural Plant Communities. U. S. D. A. Soil Conservation Service, Portland, OR. 1976.

21. Hoffer, R. M. (Purdue Univ.). Digital Processing of Landsat MSS and Topographic Data to Improve Capabilities for Computerized Mapping of Forest Cover Types. Quarterly Progress Report. 16 Jun.-15 Sept. 1978. (E79 10183). September 1978.

TABLE B-2c. REFERENCE ON TRANSPORT AND DIFFISION (METEOROLOGY) SUBJECTS

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	1		X	X		X	X	X			X	X	Wind, Field, Turbulence
	2		X	X		X	X	X			X	X	Wind, Turbulence, Field
	3		X	X		X	X					X	Snowfall, Snowpack, Field
	4	X				X	X			X	X		PBL, Theory, Field
	5	X				X	X				X	X	Wind, PBL, Theory, Field
	6		X	X		X	X					X	Precipitation, Field
	7		X	X			X	X		X	X		Lee Waves, Wind, Field
	8	X				X				X	X		Wind, Turbulence, Field, Lab
	9	X			X	X			X	X			Wind, Turbulence, Wakes, Field
	10	X			X	X			X	X			Wind, Turbulence, Wakes, Field
	11		X	X			X	X		X	X		Lee Waves, Wind, Field, Theory
	12		X	X		X	X	X			X	X	Wind, Field
	13	X				X	X	X		X			Satellite Temperature Soundings
	14	X					X	X		X	X	X	Wind, Turbulence, Field
	15	X	X		X	X			X	X	X		Wind, Turbulence, Power Plant Plumes
	16	X				X	X	X	X	X	X	X	Transmission of Electromagnetic Waves
	17		X				X	X				X	Temperature Extremes
	18	X			X	X			X	X			ASCOT Report, Wind, Turbulence
	19	X			X	X			X	X			ASCOT Report, Wind, Turbulence
	20		X			X	X			X	X		Wind, Turbulence, Model
	21	X				X				X			Wind, Turbulence, Field, Model
	22	X				X				X			Wind, Turbulence, Field, Model
	23	X					X	X		X	X	X	Satellite Observations, Climate
	24	X	X		X	X	X		X	X	X		Wind, Turbulence, Field
	25			X		X				X			Nighttime Drainage in C-a
	26		X				X			X			Convective Development

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	27	X				X	X			X			PBL, Theory (field)
	28	X						X		X	X		Regional Numerical Weather Prediction
	29	X					X			X	X		Wind, Mass-Consistent Model
	30	X						X		X	X	X	Precipitation Gridding Technique
	31	X				X	X	X		X	X	X	Convection and Heat Transfer
	32	X	X			X	X	X		X	X	X	National Wind Data Sources
	33	X				X			X	X			Wind and Turbulence in Valleys (field)
	34		X			X			X	X			Wind and Turbulence in a Canyon (field)
	35	X			X	X	X	X	X	X	X	X	Handbook on Atmospheric Diffusion
	36	X				X	X			X			Wind, Turbulence, PBL, Theory, Field
	37	X				X			X	X			Drainage Winds ~ Using Neutral-Lift Balloons
	38	X			X	X			X	X			Wind and Turbulence in Complex Terrain (field and model)
	39	X			X				X	X			Wind and Turbulence Around Buildings (field, lab, model)
	40	X				X			X	X			Wind and Turbulence in a Valley (field, theory)
	41	X				X			X	X			Wind and Turbulence in a Valley (field)
	42	X			X	X			X	X			Radiation Studies in a Canopy (model)

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	43	X				X			X	X	X		Wind and Turbulence in a Valley (field)
	44	X				X	X		X	X			Convective Scaling, Field and Theory
	45	X				X			X	X			Drainage Flows in Valleys (model)
	46	X				X	X			X	X		PBL Turbulence, Model
	47	X				X	X			X	X		Accuracy of Air Pollution Models
	48	X				X			X	X			Nocturnal Boundary Layer Model
	49	X			X	X			X	X			Plume Release Height versus Turbulence
	50	X			X	X			X	X	X		Wind and Turbulence, Model and Field
	51	X			X	X	X		X	X	X		Wind and Turbulence, Model and Field
	52	X			X				X	X			Wind and Turbulence Around Buildings (field, lab, model)
	53	X			X	X	X		X	X			Wind and Turbulence (field)
	54	X				X			X	X			Wind and Turbulence in a Valley (field)
	55	X				X			X	X			Drainage Flow Theory and Model
	56	X				X	X			X			Wind and Temperature Profile Models
	57	X				X			X	X			Drainage Flow Model
	58	X				X	X			X			Wind Fields in Stratified Flow (model)
	59	X			X				X	X			Wind and Turbulence Around Buildings (field, lab, model)
	60	X					X	X		X	X		Synoptic Wind and Temperatures Data for Models

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	61		X			X	X			X			PBL Diurnal Structure (field)
	62	X			X				X	X			Aerodynamics of Buildings
	63		X			X	X		X	X			Wind and Turbulence in Complex Terrain (field, lab)
	64	X					X	X		X	X		Wind Field Interpolation Scheme
	65	X	X			X	X			X	X	X	Climatic and Meteorological Data
	66			X		X			X	X			Tracer Study at C-a
	67			X		X	X		X	X			Mixing Layer Growth (field)
	68	X				X			X	X			Nonstationary Nocturnal BL Model
	69		X	X		X	X					X	Mean Annual Precipitation
	70	X				X	X			X	X		Wind Speed Profiles
	71	X				X	X		X	X			Wind Fluctuations over Complex Terrain
	72	X				X				X	X	X	The Urban Climate
	73	X						X				X	The Earth's Climate
	74	X				X	X		X	X	X		Turbulence Above Plant Canopies
	75	X				X	X			X	X		Numerical Modeling of PBL
	76	X				X	X			X	X		PBL Similarity Profiles via 2nd Order Closure
	77	X				X	X			X			Model, Nocturnal Surface Inversion Height
	78	X			X	X			X	X			Gaussian Plume Model, Moment Conserving
	79	X				X	X			X			Simple Mixed Layer Model
	80	X				X				X			Dispersion over Open Water
	81	X				X	X				X	X	Inadvertent Weather Modification

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	82	X	X				X	X		X	X	X	National Thunderstorm Frequencies
	83		X			X			X	X			Field Study of Transport Near Climax, Colorado
	84		X				X			X	X	X	Orographic Effects on Precipitation
	85	X				X				X			Laboratory Studies of Flow in Complex Terrain
	86	X				X				X			Laboratory Studies of Flow in Complex Terrain
	87	X			X				X	X			Flow and Transport Around Buildings
	88	X			X	X			X	X			Laboratory Modeling of Plume Dynamics
	89	X			X	X			X	X			Hydraulic Modeling of Flow and Dispersion
	90	X			X	X			X	X			Feedback Mechanisms in Clouds
	91	X			X	X			X	X			Night-time Flow and Dispersion in Valleys
	92	X			X				X	X			Modeling Flow Around Bodies
	93	X			X				X	X			Flow and Dispersion Around Bodies (lab)
	94	X			X				X	X			Flow and Dispersion Around Bodies (lab)
	95	X				X	X		X	X			Flow and Dispersion in Convective PBL (lab)
	96	X			X				X	X			Flow Around Buildings (field)
	97	X			X	X	X		X	X	X		Good Survey on the PBL
	98	X	X		X	X	X		X	X	X		Survey of Studies in Complex Terrain

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Meteorology	99	X	X		X	X	X		X	X	X	X	Survey of Studies in Complex Terrain
	100	X	X			X	X					X	Extreme Temperatures
	101			X		X	X			X			Tracer and Wind Tunnel Studies in Colorado
	102	X				X	X			X			Flow Over High Trees
	103	X			X	X			X	X			Night-time Winds in Valleys
	104	X			X	X			X	X			Dispersion Over Coastal Mountains
	105	X				X	X			X			Potential Temperature Analysis Over Mountains
	106	X	X		X	X			X	X			Power Plant Plumes Over Complex Terrain
	107	X			X	X			X	X			Night-time Drainage Winds in Valleys
	108	X			X	X			X	X			Diffusion Coefficients for Valleys
	109	X	X			X	X			X	X		National Fire Weather Data
	110	X	X			X	X			X	X		National Fire Weather Data
	111	X			X				X	X			Laboratory Modeling of Plume Rise
	112	X			X				X	X			Laboratory Modeling of Plume Rise
	113	X			X	X			X	X			Fluid Modeling of Diffusion
	114	X			X	X			X	X			Statistics of Rainfall
	115	X			X				X	X			Dispersion Behind Fences
	116	X			X	X				X			Convective Velocity Scaling
	117	X				X	X			X			PBL Scaling Considerations
	118	X				X			X	X			Wind Fluctuations in Surface Layer

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	119	X				X	X		X	X			Potential Temperature and Humidity Profiles in Convective B.L.
	120	X			X	X	X			X	X		Vertical Temperature Profiles in PBL
	121	X				X				X			Wind Structure Over a City
	122	X			X	X	X		X	X			Temperature Fluctuations in the Surface Layer
	123	X			X	X	X		X	X			Turbulence in Inversion and Convective B.L.
	124	X				X				X			Ground-Based Inversions
	125	X			X	X			X	X			Cross-Valley Flow
	126	X			X	X			X	X			Topographic Effect on Surface Winds
	127	X			X	X			X	X			Wind Tunnel Testing of Plume Dispersion
	128	X			X				X	X			Dispersion Around Buildings
	129	X					X			X			Mesoscale Puff-Diffusion Model
	130	X			X	X			X	X			ASCOT Progress Report
	131	X				X	X		X	X			Diffusion Over Forests
	132	X				X			X	X			Modeling of Flow Over Sudden Changes in Roughness
	133	X			X	X			X	X			Stable Flow Around Obstacles
	134	X			X	X	X		X	X			Aircraft Studies of PBL Evolution
	135	X			X	X	X		X	X			Erosion Processes Causing Nocturnal PBL Dispersion
	136	X			X	X	X			X			Review of PBL Flux-Profile Relationships
	137	X				X	X			X			Model of a Weather Front

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	138	X			X	X	X		X	X			Diffusion Above and Within Forests
	139	X			X	X	X		X	X			Eddy Fluxes Above Forests
	140	X			X	X			X	X			Model of the PBL
	141	X				X	X		X	X			GARP Mountain Subprogram
	142	X			X	X			X	X			Convective Cells in the PBL
	143	X			X	X				X			PBL Transport Processes Studied Via Radon Fluxes
	144	X				X	X			X			Waves in the Night-time BL
	145	X			X	X				X			Comparison Diffusion Coefficients
	146	X			X	X			X	X			Daytime Convectively-Driven BLs
	147	X					X			X			Modeling of PBL on the Synoptic Scale
	148	X			X	X	X			X			Surface Stress From Vertical Velocity Spectra
	149	X			X	X	X			X			Vertical Motion Over Land and Water
	150	X					X	X		X			Modeling of Trajectories Through Storms
	151	X			X	X			X	X	X		ISC Dispersion Model
	152	X			X				X	X			Building Downwash Modeling
	153			X	X	X			X	X			Piceance Creek Tracer Studies
	154	X	X				X	X			X	X	Orography and General Circulation
	155	X				X	X		X	X			Orographically-Enhanced Precipitation
	156		X			X	X		X	X			Mountain Waves Over the Rockies
	157	X			X	X			X	X			Modeling of Flow Over Hills

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Meteorology	158	X			X	X		X	X	X	X		Modeling of Stratified Fluids
	159	X					X		X	X			Use of Satellites to Study Orographic Flow
	160	X			X	X			X	X			Fluid Modeling of Flow Around a Hill
	161	X	X		X	X			X	X			Modelinf of Stratified Flow Around a Small Hill
	162	X			X	X			X	X			Model of Stable Flow Over a Hill
	163	X			X	X			X	X			Fluid Modeling of Flow Over a Small Hill
	164	X			X	X			X	X			Modeling Dispersion Around a Small Hill
	165	X	X			X	X		X	X			Numerical Simulation of Airflow-Complex Terrain
	166		X			X	X		X	X			Mountain Waves Over the Rockies
	167		X			X	X		X	X			Rocky Mountain Winds, Modeling and Theory
	168	X						X			X	X	Large Scale Motions in the Atmosphere
	169	X						X			X	X	Chemical Tracers of Large Scale Motions
	170	X						X			X	X	Hydrodynamic Tracers of Large Scale Motions
	171	X						X			X	X	Radioactive Tracers of Large Scale Motions
	172	X			X	X	X		X	X			Model of Convective BL
	173	X			X	X	X		X	X			Survey of Wind Field Models
	174	X			X	X			X	X			Wind Tunnel Models of Flow Around Buildings

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	175	X				X	X		X	X			Mountain Wave and Shear Studies
	176	X				X	X		X	X			Mountain Wave and Shear Theory
	177	X			X	X			X	X			Review of Wind Tunnel Modeling
	178		X	X	X	X	X					X	Precipitation Maps for Utah
	179			X		X	X			X	X		Oil Shale Impact on Flat Tops (model)
	180			X		X	X				X	X	Air Quality in Piceance Basin (model)
	181		X	X		X	X	X		X	X	X	Air Quality Impacts in Oil Shale Region (model)
	182			X	X	X				X	X	X	Meteor. and Air Quality Monitoring on C-a
	183		X	X			X	X		X	X	X	Green River Modeling Program
	184			X		X	X			X	X		Field Study in Colorado Oil Shale Area
	185			X	X	X				X	X		Local Modeling in the Oil Shale Area
	186			X		X	X			X	X		Modeling Over the Oil Shale Area
	187			X	X	X				X	X		Upper Air Meteor. Measurements in Colorado
	188			X	X	X				X	X		Upper Air Meteor. Measurements in Colorado
	189			X	X	X			X	X			Tracer Study Over Tract C-a
	190			X	X	X			X	X			Tracer Study Over Trace C-a
	191		X			X				X			Atmospheric Stability Study
	192			X	X	X				X	X	X	Meteor. and Air Quality Studies Over Utah Tracts
	193		X				X	X			X	X	Climatological Data Over Utah and Colorado

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	194			X	X	X				X	X	X	Air Quality Over Tract C-b
	195			X	X	X				X	X	X	Meteor. and Air Quality Over C-b
	196			X	X	X				X	X	X	Meteor. and Air Quality Over C-b
	197			X	X	X	X			X	X	X	PSD Implication of Oil Shale Development
	198			X		X		X		X	X	X	Atmospheric Data for Piceance Basin
	199			X	X	X	X			X	X	X	Dispersion Potential in the Piceance Basin
	200		X		X	X			X	X			Inversion Breakup in Valleys
	201			X	X	X	X			X	X	X	Meteor. and Air Quality Baseline Data
	202			X	X	X	X			X	X	X	Meteor. and Air Quality Baseline Data
	203			X	X	X	X	X		X	X	X	Meteor. and Air Quality Baseline Data
	204			X	X	X	X			X	X	X	Meteor. and Air Quality Data Over the Oil Shale Area
	205			X	X	X				X			Tracer Experiments in Parachute Creek Valley
	206			X	X	X				X			Tracer Experiments Over Roan Plateau
	207			X	X	X				X			Discussion and Analysis of Tracer Experiments in No. 205 and No. 206
	208			X	X	X				X			Tracer Study on Tract C-b
	209			X	X	X	X			X	X	X	Air Quality Impacts of Oil Shale Development
	210	X			X	X	X		X	X			New Puff Model

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Meteorology	211			X	X	X			X	X			Nocturnal Drainage Flows at Tract C-a
	212	X			X	X	X		X	X			Dispersion Models for Complex Terrain
	213	X			X				X	X			Building Wake Studies
	214	X			X	X			X	X			Bulding Wake Studies
	215	X			X	X			X	X			Numerical Model of Fumigation During Inversion Breakup
	216	X				X	X		X	X			Diurnal BL Development Over Slopes (model)
	217	X			X	X	X		X	X			Surface Fluxes of Heat and Moisture (model)
	218	X				X	X			X			Terrain-Following Coordinate Systems
	219		X		X	X			X	X			Inversion Breakups in Valleys (field)
	220		X		X	X			X	X			Inversion Breakups in Valleys (model)
	221		X		X	X				X			Infrared Radiation in Valleys
	222		X		X	X				X			Air Pollution Implications of Valley Inversions
	223		X		X	X				X			Air Pollution Implications of Valley Inversions
	224	X		X	X						X	X	SO_2 Pollution in Urban Areas
	225	X			X	X					X	X	SO_2 Pollution in Urban Areas
	226	X			X	X	X		X	X			Air Quality Model for Complex Terrain
	227	X	X			X	X	X		X	X	X	NOAA Wind Data
	228	X			X	X			X	X			Finite Element Modeling of PBL
	229	X			X	X			X	X			Internal Boundary Layer Development (model)

(continued)

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TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Meteorology	230	X			X	X			X	X			Dispersion in Stable Boundary Layers
	231	X			X	X			X	X			Computer Graphics Package
	232	X			X	X			X	X			Finite Element Methods
	233	X			X	X			X	X			Buoyant Jets in Natural Flows
	234	X			X	X	X		X	X			Use of Cubic Splines and Chapeau Functions
	235	X			X	X			X	X			Finite Element Analysis
	236	X			X	X	X		X	X			Various Grid Schemes
	237	X			X	X			X	X			Drainage Flow Models
	238	X			X	X			X	X			Drainage Flow Models
	239		X		X	X	X		X	X			Turbulence in a Desert Boundary Layer
	240	X					X	X		X			Pseudo-spectra Model
	241	X			X	X			X	X			EPRI Plume Validation Study
	242	X			X	X			X	X			EPRI Plume Validation Study
	243	X			X	X	X			X	X	X	EPA Models for Air Quality
	244	X			X	X	X			X	X	X	EPA Models for Air Quality
	245	X			X	X	X			X	X	X	EPA Models for Air Quality
	246	X					X		X	X			Mesoscale Flow Model
	247	X			X	X			X	X			Dispersion Model
	248	X				X	X			X			Potential Flow Model Over Complex Terrain
	249	X				X	X			X			Solar Radiation Model
	250	X			X	X				X			Vertical Diffusion in a Diurnally Varying Boundary
	251	X			X	X			X	X			Gaussian Plumes versus Grid Dispersion Models
	252	X			X	X	X			X			Albedo of Snow
	253	X			X	X	X			X			Vertical Velocity Profiles

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TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Meteorology	254	X			X	X			X	X			2nd Order Closure Model of Fog and Low-Level Stratus
	255	X			X	X			X	X			Morning Transition of the PBL
	256	X			X	X			X	X			Role of Thermals in the Covective BL
	257	X			X	X	X			X			Modeling Depth of Stable BL
	258	X			X	X	X		X	X			Temperature Fluctuations in the Surface Layer
	259		X				X			X	X	X	Orographic Effects on Precipitation
	260		X			X	X		X	X			PBL Diurnal Structure (model)
	261	X			X	X	X		X	X	X		Horizontal Diffusion Model
	262	X					X			X			Models for Winds and Air Quality
	263	X			X	X	X		X	X			Model of Convective Heat Exchange in PBL
	264	X				X	X			X			Nonhydrostatic Mesoscale Flow Model
	265	X			X	X	X		X	X			Temperature Structure in the Surface Layer
	266	X			X	X	X			X			Wind Field Model
	267		X		X	X				X			Nocturnal Drainage Flows
	268	X			X	X	X			X			Wind Fields in Nonstationary PBLs
	269	X			X	X				X			Katabatic Wind Model
	270	X			X	X	X			X			Wind in Nocturnal BL (model and field)
	271	X					X	X		X			Isentropic Trajectories (model)
	272		X				X	X		X			Green's Function Wind Models Over Topography

(continued)

TABLE B-2c. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Meteorology	273	X					X	X		X			Model of Quasi-Geostrophic Flow Over Mountains
	274	X				X	X			X			Semi-Implicit Mesoscale Flow Model
	275	X			X	X			X	X			Turbulence Measurements Above Forest Canopies
	END	-	-	-	-	-	-	-	-	-	-	-	--

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(PREVIOUSLY C/N: EPA FORM 287)
TYPING GUIDE SHEET

REFERENCES

c. Meteorology

1. Elliott, D. L. and W. R. Barchet. Wind Energy Resource Atlas: Volume 1-the Northwest Region. PNL-3195, WERA-1. Pacific Northwest Laboratory, Richland, WA. 1980.

2. Anderson, S. R., et al. Wind Energy Resource Atlas: Volume 8 - the Southern Rocky Mountain Region. PNL-3195, WERA-8. Pacific Northwest Laboratory, Richland, WA. 1981.

3. Weisbecker, L. W. The Impacts of Snow Enhancement: Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin. Univ. of Oklahoma Press, Norman, Oklahoma. 1974.

4. McBean, G. A., et al. The Planetary Boundary Layer. Tech. Note No. 165. (WMO-No. 530). World Meteorological Organization, Geneva, Switzerland. 1979.

5. Hiester, T. R. and W. T. Pennell. The Meteorological Aspects of Siting Large Wind Turbines. PNL-2522. Pacific Northwest Laboratory, Richland, WA. 1981.

6. Keefer, T. N. and R. S. McQuivey. Water Availability for Development of Major Tar Sands Areas in Utah. LETC-0013-1. Sutron Corp., Arlington, VA. 1979.

7. Lilly, D., et al. Data Catalog for the 1970 Colorado Lee Wave Observational Program. NCAR-TN/STR-72. National Center for Atmospheric Research, Boulder, CO. 1971.

8. Hovind, E. L., et al. Workshop on Atmospheric Dispersion Models in Complex Terrain. EPA-600/9-79-041. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1979.

9. Start, G. E., et al. Rancho Seco Building Wake Effects on Atmospheric Diffusion. NUREG/CR-0456. U. S. Nuclear Regulatory Commission, Washington, D.C. 1978.

10. Start, G. E., et al. EOCR Building Wake Effects on Atmospheric Diffusion. NUREG/CR-1395. U. S. Nuclear Regulatory Commission, Washington, D.C. 1980.

11. Scheetz, V. R., et al. Colorado Severe Downslope Windstorms: A Prediction Technique. Geophysical Research and Development Corp., Fort Collins, CO. 1976.

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TYPING GUIDE SHEET

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12. Marwitz, J. D. and K. B. Gilkey. Catalog of Available Wind Data in Idaho, Montana and Wyoming. RLO-2343-79/1. Dept. of Atm. Sci., Univ. of Wyoming, Laramie, WY. 1979.

13. Fritz, S., et al. Temperature Sounding From Satellites. NOAA Tech. Rep. Ness. 59. National Oceanic and Atmospheric Administration, Dept. of Comm., Washington, D.C. 1972.

14. Holzworth, G. C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States. Publ. No. AP-101. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1972.

15. Koch, R. C., et al. Power Plant Stack Plumes in Complex Terrain: An Appraisal of Current Research. EPA-600/7-77-020. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1977.

16. Falcone, V. J., Jr. and R. Dyer. Refraction, Attenuation, and Backscattering of Electromagnetic Waves in the Troposphere: A Revision of Chapter 9, Handbook of Geophysics and Space Environments. AFCRL-70-0007. U. S. Air Force, (Air Force Cambridge Research Laboratories), Bedford, MA. 1970.

17. Nicodemus, M. L. and N. B. Guttman. Probability Estimates of Temperature Extremes for the Contiguous United States. NUREG/CR-1390. U. S. Nuclear Regulatory Commission, Washington, D.C. 1980.

18. Dickerson, M. H. and P. H. Gudiksen. ASCOT FY-1980 Progress Report. UCID-18878/ASCOT-80-10. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

19. Dickerson, M. H. and P. H. Gudiksen. ASCOT FY-1979 Progress Report UCRL-52899/ASCOT/80/1. Lawrence Livermore Laboratory, Livermore, CA. 1980.

20. Hughes, R. L. A Numerical Simulation of Mesoscale Flow Over Mountainous Terrain. Atm. Sci. Paper No. 303. Dept. of Atm. Sci., Colorado State Univ., Fort Collins, CO. 1978.

21. Londergan, R. J. and J. J. Mangano. An Evolution of Short-Term Air Quality Models Using Tracer Study Data: Volume II - Relative Concentration Plots. API Report No. 4333. American Petroleum Institute, Washington, D.C. 1980.

22. Londergan, R. J., et al. An Evaluation of Short-Term Air Quality Models Using Tracer Study Data: Volume I. API Report No. 4333. American Petroleum Institute, Washington, D.C. 1980.

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3/8"
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PAGE NUMBER
EPA Form 2300-4 (6-80)
TYPING GUIDE SHEET

23. Ruttenburg, Stan (Editor). Status of Satellite Observing Possibilities for Studies of Climate Physical Processes. National Center for Atmospheric Research. Boulder, CO. 1978.

24. Orgill, M. M. Survey of Wind Measurement Field Programs. BNWL-2220/WIND-3. Battelle, Pacific Northwest Laboratories, Richland, WA. 1977.

25. Clements, W. E., *et al*. Experimental Design and Data of the August 1980 Corral Gulch Nocturnal Wind Experiment, Piceance Basin, Northwestern Colorado. LA-8895-MS. (Prepared for). U. S. Environmental Protection Agency, Cincinnati, Ohio. 1981.

26. George, R. L. Evolution of Mesoscale Convective Systems over Mountainous Terrain. Atm. Sci. Paper No. 318. Dept. of Atm. Sci., Colorado State University, Fort Collins, CO. 1979.

27. Panofsky, H. A. "Matching in the Convective Planetary Boundary Layer." J. Atm. Sci. 35. 1978. pp. 272-276.

28. Kreitzberg, C. W., *et al*. "Progress and Problems in Regional Numerical Weather Prediction." SIAM-AMS Proc. Vol. II. 1978. pp. 32-58.

29. Walton, J. J., *et al*. Wind-Power Site-Screening Methodology: Final Report. UCRL-52938. Lawrence Livermore Laboratory, Livermore, CA. 1980.

30. Mayerhofer, P. M. A Precipitation Data Gridding Program: Program Description and Users Guide. SRI, Inc., Palo Alto, CA. 1980.

31. Webb, E. K. Convection Mechanisms of Atmospheric Heat Transfer from Surface to Global Scales. Pres. at 2nd Australian Conf. on Heat and Mass Transfer. Held at the Univ. of Sydney in Feb. 1977.

32. Changery, M. J. National Wind Data Index Final Report. HCO/T1041-01. National Climate Center, Asheville, N.C. 1978.

33. Clements, W. E., *et al*. Effective Transport Velocity and Plume Elongation in Nocturnal Valley Wind Fields. Pres. at Second Joint Conf. on Appl. of Air Poll. Meteor. and Second Conf. on Industrial Meteor. Sponsored by Amer. Meteor. Soc. at New Orleans, LA on 24-28 March, 1980.

34. Start, G. E., *et al*. Diffusion in a Canyon within Rough Mountainous Terrain. NOAA Tech. Memo. ERL/ARL-38. National Oceanic and Atmospheric Administration, Air Resources Laboratories, Idaho Falls, Idaho. 1973.

35. Hanna, S. R., *et al*. Handbook on Atmospheric Diffusion. Dept. of Energy, Tech. Info. Center, Oak Ridge, TN. 1980.

EPA Form 2350-6 (4-80)
(PREVIOUSLY CIR. EPA FORM 257)
TYPING GUIDE SHEET

36. Hanna, S. R. "Lagrangian and Eulerian Time-Scale Relations in the Daytime Boundary Layer." J. of Appl. Meteor. Vol. 20. 1981. pp. 242-249.

37. Nappo, C. J., *et al*. Drainage Wind Observations Using Neutral-Lift Balloons. Proc. of 2nd Joint Conf. on Appl. of Air Pollution Meteor. and 2nd Conf. on Industrial Meteor. Held 24-28 March 1980 in New Orleans, LA. Sponsored by Amer. Meteor. Soc. 1980. pp. 495-498.

38. Hanna, S. R. Complex Terrain Influence on σ_θ and σ_y at TVA's Widow Creek Steam Plant. Proc. of 2nd Joint Conf. on Appl. of Air Pollution Meteor. and 2nd Conf. on Industrial Meteor. Held 24-28 March 1980 in New Orleans, LA. Sponsored by Amer. Meteor. Soc. 1980. pp. 567-570.

39. Hosker, R. P., Jr. Dispersion in the Vicinity of Buildings. Proc. of 2nd Joint Conf. on Appl. of Air Pollution Meteor. and 2nd Conf. on Industrial Meteor. held 24-28 March 1980 in New Orleans, LA. Sponsored by Amer. Meteor. Soc. 1980. pp. 92-107.

40. Hosker, R. P., *et al*. Experimental Methods and Preliminary Analyses of Drainage Flow Observations During the First ASCOT Field Study. Proc. of 2nd Joint Conf. on Appl. of Air Pollution Meteor. and 2nd Conf. on Industrial Meteor. held 24-28 March 1980 in New Orleans, LA. Sponsored by Amer. Meteor. Soc. 1980. pp. 488-498.

41. Nappo, C. J. and H. F. Snodgrass. Observation of Nighttime Winds Using Pilot Balloons in Anderson Creek Valley, Geysers, California. Submitted to J. of Appl. Meteor. 1980.

42. Smith, J. A., *et al*. Thermal Vegetation Canopy Model Studies. Submitted to Remote Sensing of the Environment. 1980.

43. Hanna, S. R. Diurnal Variation of Horizontal Wind Direction Fluctuations σ_θ in Complex Terrain at Geysers, CA. Accepted for publication in Boundary Layer Meteorology. 1980.

44. Briggs, G. A. What Convective Scaling Does for Diffusion Data. Publ. in Proc. of Workshop on Diffusion from Tall Stacks in Convective Conditions, Toronto, Canada (held May 1979). 1980.

45. Briggs, G. A. Canopy Effects on Predicted Drainage Flow Characteristics and Comparisons with Observations. Proc. of 5th Symp. on Turbulence, Diffusion, and Air Pollution. Held in Atlanta, GA on 9-13 March 1981. pp. 113-115.

46. Hanna, S. R. Turbulent Energy and Lagrangian Time Scales in the Planetary Boundary Layer. Proc. of 5th Symp. on Turbulence, Diffusion, and Air Pollution. Held in Atlanta, GA on 9-13 March 1981, pp. 61-62.

47. Nappo, C. J. A Note of the Fundamental Accuracy of Air Pollution Models. Proc. of Symp. on Intermediate Range Atmospheric Transport Processes and Technology Assessment. Held in Gatlinburg, TN on 1-3 October 1980.

48. Rao, K. S. and H. F. Snodgrass. The Nocturnal Boundary Layer Over A Sloping Surface. Proc. of 5th Symp. on Turbulence, Diffusion and Air Pollution. Held in Atlanta, GA, on 9-13 March 1981, pp. 106-108.

49. Hanna, S. R. Effects of Release Height on σ_y and σ_z in Daytime Conditions. Proc. of NATO-CCMS Conference at Amsterdam, the Netherlands,on 25-28 November, 1980.

50. Hanna, S. R., _et al_. Plume Diffusion Modeling - An Annual Report to the Nuclear Regulatory Commission. NOAA Publ., Oak Ridge, TN. 1980.

51. Gifford, F. A. Recent Studies of Diffusion Parameters for Air Pollution Applications. NOAA Publ., Oak Ridge, TN. 1979.

52. Hosker, R. P., Jr. Flow and Diffusion Near Obstacles. Chapter 7 in Atm. Sci. and Power Production. Editor-D. Randerson- U.S. Dept. of Energy Tech. Info. Center, Oak Ridge, TN. 1979.

53. Hanna, S. R. Phoenix Lagrangian Turbulence Observations Using Pibals and Tetroons. Project Phoenix-the September 1978 Field Operation NOAA/ERL Propogation Lab & NCAR, Dec. 1979, Boulder, CO. Chapter 12. 1979. pp. 138-149.

54. Nappo, C. J., _et al_. Hourly-Averaged Mast Data, Tethered Balloon Temperature Soundings, and Neutral-Density Balloon Trajectories Observed in Nocturnal Drainage Flows During the First ASCOT Field Study on Anderson Creek, CA. NOAA Publ., Oak Ridge, TN. 1979.

55. Briggs, G. A. Entrainment Coefficient Versus Ri for Drainage Flows and Compatibility with Turbulence Scaling Assumptions. NOAA Publ.,Oak Ridge, TN. 1979.

56. Culkowski, W. M. The Logarithmic Integral as a Functional for Estimating Wind and Temperature Profiles in Unstable Cases. NOAA., Oak Ridge, TN. 1979.

57. Briggs, G. A. Analytic Modeling of Drainage Flows. NOAA Publ., Oak Ridge, TN. 1979.

58. Agopian, K. G. and S. C. Crow. The Effect of Atmospheric Density Stratification on Wind Turbine Siting. RLO-2444-78/1. Poseidon Research, Los Angeles, CA. 1978.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 237)
TYPING GUIDE SHEET

59. Hosker, R. P., Jr. Dispersion in the Vicinity of Buildings. Pres. at 2nd Joint Conf. on Appl. of Air Pollution Meteor. and 2nd Conf. on Industrial Meteor. Held on 24-28 March 1980 at New Orleans, LA. Sponsored by Amer. Meteor. Soc. 1980. pp. 92-107.

60. Heffter, J. L. Observed Meteorological Data Bases for Pollution Modeling. Air Resources Laboratory. National Oceanic and Atmospheric Administration, Silver Springs, MD. 1980.

61. Banta, R. and W. R. Cotton. Horizontal and Vertical Structure of Diurnal Boundary Layer Flow Patterns Over Mountainous Terrain. Pres. at 4th Symp. on Turb. Diff. and Air Poll. Held 15-18 Jan. 1979 at Reno, NV. Sponsored by Amer. Meteor. Soc. 1979. pp. 217-224.

62. Cermak, J. E. "Aerodynamics of Buildings." Annual Review of Fluid Mechanics. Vol. 8. 197. 1976. pp. 75-106.

63. Orgill, M. M. and J. E. Cermak. Atmospheric Flow and Diffusion Over Mountainous Terrain. AIAA Paper No. 72-648. Pres. at AIAA 5th Fluid and Plasma Dynamics Conf. Held 26-28 June 1972 at Boston, MA. 1972.

64. Barnes, S. L. "A Technique for Maximizing Details in Numerical Weather Map Analysis." J. of Appl. Meteor. Vol. 3. 1964. pp. 396-409.

65. Kaufman, J. W. (Editor). Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1977 Revision. NASA Tech. Memo 78118. National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama. 1977.

66. Sehmel, G. A. An Atmospheric Tracer Investigation of Fugitive-Emission Transport in the Colorado Oil Shale Region. PNL-SA-9834. Pacific Northwest Laboratory, Richland, WA. 1981.

67. Laulainen, N.S., et al. Mixing Layer Growth and Background Air Quality Measurements Over the Colorado Oil Shale Area. PNL-SA-9358. Pacific Northwest Laboratory, Richland, WA. 1981.

68. Rao, K. S. and H. F. Snodgrass. "A Nonstationary Nocturnal Drainage Flow Model." Boundary-Layer Meteorology. 20. 1981. pp. 309-320.

69. Karlinger, M. R. and J. A. Skrivan. Kriging Analysis of Mean Annual Precipitation, Powder River Basin, Montana and Wyoming. USGS/WRI-80-50. U. S. Geological Survey, Tacoma, WA. 1981.

70. Mikhail, A. S. and C. G. Justus. Height Projection Methods and Sensitivity Studies. Technical Report. DOE/ET/20355-T1. U. S. Dept. of Energy, Washington, D.C. 1979.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)

TYPING GUIDE SHEET

71. Dutton, J. A., *et al.* Statistics of Wind Fluctuations Over Complex Terrain. DOE/ET/20560-1. U. S. DOE, Washington, D.C. 1979.

72. Landsberg, H. E. The Urban Climate. Institute of Physical Science and Technology. Univ. of Maryland, College Park, MD. 1981.

73. Budyko, I. The Earth's Climate: Past and Future. Academic Press, New York, N.Y. 1981.

74. Van Dyke, M. and J. V. Wehausen (Editors). Annual Review of Fluid Mechanics. Vol. 13. 1981. Annual Review, Inc., Palo Alto, CA. 1981.

75. Bodin, S. Applied Numerical Modeling of the Atmospheric Boundary Layer. Lectures given of the "Ettore Majorana" School of Scientific Culture, Erice, Sicily. 13-27 February, 1978.

76. Yamada, T. "PBL Similarity Profiles Determined from a Level 2 Turbulence Closure Model." Boundary-Layer Meteor. 17. 1979. pp. 333-351.

77. Yamada, T. "Prediction of the Nocturnal Surface Inversion Height." J. Appl. Meteor. 18. 1979. pp. 526-531.

78. Shannon, J. D. "A Gaussian Moment-Conservation Diffusion Model." J. Appl. Meteor. 18. 1979. pp. 1406-1414.

79. Yamada, T. and S. Berman. "An Evaluation of a Simple Mixed-Layer Model with Penetrative Convection." J. Appl. Meteor. 18. 1979. pp. 781-786.

80. Sheih, C. M., *et al.* "Measurement of Lagrangian Atmospheric Dispersion Statistics Over Open Water." J. Appl. Meteor. 19. 1980. pp. 497-504.

81. Auer, A. H., Jr. "Correlation of Land Use and Cover with Meteorological Anomalies." J. of Appl. Meteor. 17. 1978. pp. 636-643.

82. Changery, M. J. National Thunderstorm Frequencies for the Contiguous United States. NUREG/CR-2252. U. S. Nuclear Regulatory Commission, Washington, D.C. 1981.

83. Reid, J. D. "Studies of Pollutant Transport and Turbulent Dispersion over Rugged Mountainous Terrain Near Climax Colorado." Symp. on Sierra Nevada Meteorology. Held at South Lake Tahoe, CA. June 19-21, 1978. Sponsored by Amer. Meteor. Soc. 1978. pp. 34-37.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

84. Houghton, J. G. "Orographic Effects on Great Basin Precipitation." Symp. on Sierra Nevada Meteorology held at South Lake Tahoe, CA. June 19-21, 1978. Sponsored by Amer. Meteor. Soc. 1978. pp. 109-110.

85. Lin, J. T., et al. Laboratory and Numerical Simulation of Plume Dispersion in Stably Stratified Flow Over Complex Terrain. EPA-650/4-74-044. U. S. EPA, Washington, D.C. 1974.

86. Liu, H. T. and J. T. Lin. Plume Dispersion in Stably Stratified Flows Over Complex Terrain. EPA-600/4-76-022. U. S. EPA, Research Triangle Park, N.C.

87. Vincent, J. H. "Model Experiments on the Nature of Air Pollution Transport Near Buildings." Atmos. Environ. 11. 1977. pp. 765-774.

88. Riley, J. J. and D. P. Delisi. Survey of Laboratory Modeling of Plume Dynamics. EPRI EA-323. Electric Power Research Institute, Palo Alto, CA. 1977.

89. Onishi, Y. and S. M. Brown. Critical Review of Hydraulic Modeling on Atmospheric Heat Dissipation. BNWL-2166. Battelle Pacific Northwest Laboratories, Richland, WA. 1977.

90. Haman, K. "The Dynamics of Stratiform Clouds." ACTA Geophysica Polonica. Vol. XX. 1972. pp. 11-23.

91. Orgill, M. M., et al. Net Radiation, Vertical Profiles of Wind and Temperature, and Cross-Valley FP Tracer Sampling in the Anderson Creek Valley Area July 1979. PNL-SA-8799. Pacific Northwest Laboratory, Richland, WA. 1980.

92. Hirt, C. W., et al. Numerical Simulation of Three-Dimensional Flow Past Bluff Bodies. LA-UR-77-1420. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1977.

93. Robins, A. G. and I. P. Castro. "A Wind Tunnel Investigation of Plume Dispersion in the Vicinity of a Surface Mounted Cube-II. The Concentration Field." Atmos. Environ. 11. 1977. pp. 299-311.

94. Robins, A. G. and I. P. Castro. "A Wind Tunnel Investigation of Plume Dispersion in the Vicinity of a Surface Mounted Cube-I. The Flow Field." Atmos. Environ. 11. 1977. pp. 291-297.

95. Willis, G. E. and J. W. Deardorff. "A Laboratory Model of Diffusion into the Convective Planetary Boundary Layer." Quart. J. R. Met. Soc. 102. 1976. pp. 427-445.

96. Frost, W., et al. "Mean Horizontal Wind Profiles Measured in the Atmospheric Boundary Layer About a Simulated Block Building." Boundary-Layer Meteorology 11. 1977. pp. 135-145.

97. McBean, G. A., *et al.* The Planetary Boundary Layer. Tech. Note No. 165. WMO-No. 530. World Meteorological Organization, Geneva, Switzerland. 1978.

98. Dickerson, M. H. (Editor). Atmospheric Studies in Complex Terrain (ASCOT): Information Survey. UCID-18572 & ASCOT-80-3. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

99. Orgill, M. M. Atmospheric Studies in Complex Terrain: A Planning Guide for Future Studies. PNL-3656 & ASCOT 80-4. Pacific Northwest Laboratory, Richland, WA. 1981.

100. Nicodemus, M. L. and N. B. Guttman. Probability Estimates of Temperature Extremes for the Contiguous United States. NUREG/CR-1390. U. S. Nuclear Regulatory Commission, Washington, D.C. 1980.

101. Orgill, M. M., *et al.* Research and Development Technique for Estimating Airflow and Diffusion Parameters Related to the Atmospheric Water Resources Program. CER71-72-MMO-JEC-LOG-20. Dept. of Civil Eng., Colorado State University, Fort Collins, CO. 1972.

102. Garratt, J. R. "Transfer Characteristics for a Heterogeneous Surface of Large Aerodynamic Roughness." Quart. J. R. Met. Soc., 104. 1978. pp. 491-502.

103. Nappo, C. J. Analysis of Nighttime Wind Using Neutral-Lift Balloons. ATDL/NOAA. Oak Ridge, TN. 1980.

104. Hinds, W. T. "Diffusion Over Coastal Mountains of Southern California." Atmos. Environ. 4. 1970. pp. 107-124.

105. Cramer, O. P. "Potential Temperature Analysis Over Mountainous Terrain." J. Appl. Meteor. 11. 1972. pp. 44-50.

106. Pickering, K. E., *et al.* Power Plant Stack Plumes in Complex Terrain. EPA-600/7-80-008. U. S. EPA, Research Triangle Park, NC. 1980.

107. Dickerson, M. H. (Editor). A Collection of Papers Based on Drainage Wind Studies in the Geysers Area of Northern California: Part I. UCID-18884 & ASCOT-80-7. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

108. Minott, D. H., *et al.* Development of Vertical Dispersion Coefficients for Deep-Valley Terrain. TRC Rep. COO-4026-3. The Research Corp. of New England, Wethersfield, Connecticut. 1977.

109. Marlatt, W. E., *et al.* Assessment of the Applicability of the National Fire Weather Data Library to Wind Energy Analysis. PNL-2538. Pacific Northwest Laboratory, Richland, WA. 1979.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

110. Furman, R. W. and G. E. Brink. The National Fire Weather Data Library: What It Is and How to Use It? General Tech. Rep. RM-19. U. S. Dept. of Agriculture (Forest Service), Fort Collins, CO. 1975.

111. Huber, A. H. Guideline for Use of Fluid Modeling to Determine Good Engineering Practice Stack Height. EPA-450/4-79-015. U. S. EPA, Research Triangle Park, N.C. 1979.

112. Huber, A. H. and J. A. Tikvart. The Use of Good Engineering Practice Stack Heights in Air Pollution Control. Pres. at 10th International Tech. Meeting on Air Pollution Modeling and Its Appl. Held 23-26 October 1979, Rome, Italy. Sponsored by NATO. 1979.

113. Snyder, W. H. Guideline for Fluid Modeling of Atmospheric Diffusion. EPA-450/4-79-016. U. S. EPA, Research Triangle Park, N.C. 1979.

114. Drufuca, G. and R. R. Rogers. "Statistics of Rainfall Over Paths from 1 to 50 Km." Atmos. Environ. 12. 1978. pp. 2333-2342.

115. Sheih, C. M., *et al*. "Pollutant Transfer Across the Cavity Region Behind a Two-Dimensional Fence." Atmos. Environ. 12. 1978. pp. 2301-2307.

116. Venkatram, A. "Estimating the Convective Velocity Scale for Diffusion Applications." Boundary-Layer Meteorology. 15. 1978. pp. 447-452.

117. Hicks, B. B. "Comments on 'The Characteristics of Turbulent Velocity Components in the Surface Layer Under Convective Conditions', by H. A. Panofsky, H. Ternekes, D. H. Lenschow, and J. C. Wyngaard." Boundary-Layer Meteorology. 15. 1978. pp. 255-258.

118. Panofsky, H. A., *et al*. "On the Characteristics of Wind Direction Fluctuations in the Surface Layer." Boundary-Layer Meteorology. 15. 1978. pp. 439-446.

119. Manton, M. J. "Moist Penetrative Convection and the Formation of Incipient Cloud." Boundary-Layer Meteorology. 15. 1978. pp. 265-287.

120. Schönwald, B. "Determination of Vertical Temperature Profiles for the Atmospheric Boundary Layer by Ground-Based Microwave Radiometry." Boundary-Layer Meteorology. 15. 1978. pp. 453-464.

121. Jackson, P. S. "Wind Structure Near a City Centre." Boundary-Layer Meteorology. 15. 1978. pp. 323-340.

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PAGE NUMBER
EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

122. Antonia, R. A. and A. J. Chambers. "Spectra of Temperature Derivatives in the Atmospheric Surface Layer." Boundary-Layer Meteorology. 15. 1978. pp. 341-345.

123. Weill, A., *et al.* "Turbulence Structure in Temperature Inversions and in Convection Fields as Observed by Doppler Sounder." Boundary-Layer Meteorology. 15. 1978. pp. 375-390.

124. Klöppel, M., et al. "Experimental Investigations into Variations of Ground-Based Inversions and Comparisons with Results of Simple Boundary-Layer Models." Boundary-Layer Meteorology. 15. 1978. pp. 135-145.

125. Raithby, G. D., *et al.* "Measurements and Predictions of Turbulent Recirculating Flow Over a Rectangular Depression." Boundary-Layer Meteorology. 15. 1978. 181-194.

126. Weidner, G. A. and C. R. Stearns. "Topographic Influence on Surface Winds." Boundary-Layer Meteorology. 14. 1978. pp. 167-182.

127. Leutheusser, H. J. and J. Motycka. "Wind Tunnel Testing of Flue Gas Dispersion." Atmos. Environ. 12. 1978. pp. 1313-1318.

128. Vincent, J. H. "Scalon Transport in the Near Aerodynamic Wakes of Surface-Mounted Cubes." Atmos. Environ. 12. 1978. pp. 1319-1322.

129. Athey, G. F., *et al.* User's Guide to the MESOI Diffusion Model and to the Utility Programs UPDATE and LOGRVU. PNL-3999. Pacific Northwest Laboratory, Richland, WA. 1981.

130. Dickerson, M. H. and P. H. Gudiksen. ASCOT FY-1981 Progress Report UCID-18878-81 & ASCOT 81-2. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

131. Orgill, M. M., *et al.* "Some Initial Measurements of Airborne DDT Over Pacific Northwest Forests." Atmos. Environ. 10. 1976. pp. 827-834.

132. Lo, A. K. "Boundary Layer Flow Over Gentle Curvilinear Topography with a Sudden Change in Surface Roughness." Quart. J. R. Met. Soc. 103. 1977. pp. 199-209.

133. Brighton, P. W. M. "Strongly Stratified Flow Past Three-Dimensional Obstacles." Quart. J. R. Met. Soc. 104. 1978. pp. 289-307.

134. Coulman, C. E. "Boundary-Layer Evolution and Nocturnal Inversion Dispersal-Part I." Boundary-Layer Meteorology, 14. 1978. pp. 471-491.

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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY EPA FORM 447)
TYPING GUIDE SHEET

135. Coulman, C. E. "Boundary-Layer Evolution and Nocturnal Inversion Dispersal-Part II." Boundary-Layer Meteorology. 14. 1978. pp. 493-513.

136. Yaglom, A. M. "Comments on Wind and Temperature Flux-Profile Relationships." Boundary-Layer Meteorology. 11. 1977. pp. 89-102.

137. Giles, B. D. "A Three Dimensional Model of a Front." Weather. 27. 1972. pp. 352-363.

138. Petit, C., et al. "Study of Turbulent Diffusion Above and Within a Forest-Application in the Case of SO_2." Atmos. Environ. 10. 1976. pp. 1057-1063.

139. Hicks, B. B., et al. "A Study of Eddy Fluxes Over a Forest." J. Appl. Meteor. 14. 1975. pp. 58-66.

140. Yamada, T. and G. Mellor. "A Simulation of the Wangara Atmospheric Boundary Layer Data." J. Atmos. Sci. 32. 1975. pp. 2309-2329.

141. UCAR. "ALPEX: Upcoming GARP Mountain Subprogram." UCAR Newsletter. Vol. 4. University Corporation for Atmospheric Research, Boulder, CO. 1980.

142. Frisch, A. S., et al. "Observations of Boundary-Layer Convection Cells Measured by Dual-Doppler Radar and Echosounde, and by Microbarograph Array." Boundary-Layer Meteorology. 10. 1976. pp. 55-68.

143. Li, T. Y. "Diurnal Variations of Radon and Meteorological Variables Near the Ground." Boundary-Layer Meteorology. 7. 1974. pp. 185-198.

144. Fua, D., et al. "The Stability Analysis of an Inflexion-Free Velocity Profile and Its Application to the Night-Time Boundary Layer in the Atmosphere." Boundary-Layer Meteorology. 10. 1976. pp. 35-54.

145. Vogt, K. J. "Empirical Investigations of the Diffusion of Waste Air Plumes in the Atmosphere." Nuclear Technology. 34. 1977. pp. 43-57.

146. Kahn, P. H. and J. A. Businger. "The Effect of Radiative Flux Divergence on Entrainment of a Saturated Convective Boundary Layer." Quart. J. R. Met. Soc. 105. 1979. pp. 303-306

147. Brown, R. A. "Similarity Parameters from First-Order Closure and Data." Boundary-Layer Meteorology. 14. 1978. pp. 381-396.

148. Moravek, D., *et al*. "Determination of Surface Stress from Vertical-Velocity Spectra." Quart. J. R. Met. Soc. 102. 1975. pp. 260-263.

149. Merry, M. and H. A. Panofsky. "Statistics of Vertical Motion over Land and Water." Quart. J. R. Met. Soc. 102. 1976. pp. 255-260.

150. Kreitzberg, C. W. and M. J. Leach. Diagnosis and Prediction of Tropospheric Trajectories and Cleansing. Dept. of Atm. Sci. and Phys., Drexel University, Philadelphia, PA. 1978.

151. Bowers, J. F., *et al*. The Industrial Source Complex Dispersion Model. Paper No. 79-2.1. Pres. at 72nd Annual Meeting of APCA at Cincinnati, Ohio, June 24-29, 1979.

152. Hatcher, R. V., *et al*. Building Downwash Modeling - Recent Developments. Paper No. 79-2.6. Pres. at 72nd Annual Meeting of APCA at Cincinnati, Ohio, June 24-29, 1979.

153. Chan, M. W. A Tracer Experiment to Determine the Transport and Dispersion of an Elevated Plume in Complex Terrain. Paper No. 79-8.2. Pres. at 72nd Annual Meeting of APCA at Cincinnati, Ohio, June 24-29, 1979.

154. Kasahara, A. "Influence of Orography on the Atmospheric General Circulation." Orographic Effects in Planetary Flows. GARP Publ. Series No. 23, Geneva, Switzerland. (See Chapter 1). 1980.

155. Browning, K. A. "Structure, Mechanism and Prediction of Orographically-Enhanced Rain in Britain." Orographic Effects in Planetary Flows. GARP Publ. Series No. 23, Geneva, Switzerland. (See Chapter 3). 1980.

156. Klemp, J. B. and D. K. Lilly. "Mountain Waves and Momentum Flux." Orographic Effects in Planetary Flows. GARP Publ. Series No. 23, Geneva, Switzerland (See Chapter 4). 1980.

157. Taylor, P. A. and P. R. Gent. "Modification of the Boundary Layer by Orography." Orographic Effects in Planetary Flows. GARP. Publ. Series No. 23, Geneva, Switzerland (See Chapter 5). 1980.

158. Baines, P. G. and P. A. Davies. "Laboratory Studies of Topographic Effects in Rotating and/or Stratified Fluids." Orographic Effects in Planetary Flows. GARP Publ. Series No. 23, Geneva, Switzerland (See Chapter 8). 1980.

159. Gjevik, B. "Orographic Effects Revealed by Satellite Pictures: Mesoscale Flow Phenomena." Orographic Effects in Planetary Flows. GARP Publ. Series No. 23, Geneva, Switzerland (See Chapter 9). 1980.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

160. Hunt, J. C. R., et al. Flow Structure and Turbulent Diffusion Around a Three-Dimensional Hill: Fluid Modeling Study on Effects of Stratification; Part 1, Flow Structure. EPA-600/4-78-041. U. S. EPA, Research Triangle Park, N.C. 1978.

161. Snyder, W. H. Towing Tank Studies in Support of Field Experiments at Cinder Cone Butte, Idaho: Phase III: Verification of Formula for Prediction of Dividing Streamline Height. (Draft Report). U. S. EPA, Research Triangle Park, N.C. 1980.

162. Hunt, J. C. R. and W. H. Snyder. "Experiments on Stably and Neutrally Stratified Flow Over a Model Three-Dimensional Hill." J. Fluid Mechanisms. 96. 1980. pp. 671-704.

163. Snyder, W. H., *et al*. "A Fluid Modeling Study of the Flow Structure and Plume Impingement on a Three-Dimensional Hill in Stably Stratified Flow." Wind Engineering, Pergamon Press, New York, N.Y. 1980. pp. 319-329.

164. Hunt, J. C. R., *et al*. "Turbulent Diffusion from a Point Source in Stratified and Neutral Flows Around a Three-Dimensional Hill-Part I. Diffusion Equation Analysis." Atmos. Environ. 13. 1979. pp. 1227-1239.

165. Mahrer, Y. and R. A. Pielke. "A Numerical Study of the Airflow Over Irregular Terrain." Beiträge zur Physik der Atmosphäre. 50. 1977. pp. 98-113.

166. Klemp, J. B. and D. K. Lilly. "The Dynamics of Wave-Induced Downslope Winds." J. of Atmos. Sci. 32. 1975. pp. 320-339.

167. Houghton, D. D. and E. Isaacson. "Mountain Winds." Studies in Num. Anal. 2. 1968. pp. 21-52.

168. Reiter, E. R. Atmospheric Transport Processes Part 1: Energy Transfers and Transformations. DOE Critical Review Series. (From NITS as TID-24868). U. S. DOE, Washington, D.C. 1969.

169. Reiter, E. R. Atmospheric Transport Processes Part 2: Chemical Tracers. DOE Critical Review Series (From NITS as TID-25314). U. S. DOE, Washington, D.C. 1971.

170. Reiter, E. R. Atmospheric Transport Processes Part 3: Hydrodynamic Tracers. DOE Critical Review Series (From NITS as TID-25731). U. S. DOE, Washington, D.C. 1972.

171. Reiter, E. R. Atmospheric Transport Processes Part 4: Radioactive Tracers. DOE Critical Review Series (From NITS as TID-27114). U. S. DOE, Washington, D.C. 1978.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

172. Wyngaard, J. C. and O. R. Cote'. "The Evolution of a Convective Boundary Layer - A Higher-Order-Closure Model Study." Boundary-Layer Meteorology. 7. 1974. pp. 289-308.

173. Freeman, B. E. A New Wind Energy Site Selection Methodology. SAI 76-614-LJ. Science Applications, Inc., La Jolla, CA. 1976.

174. Kothari, K. M., *et al*. The Wake and Diffusion Structure Behind a Model Industrial Complex. NUREG/CR-1473. U. S. Nuclear Regulatory Commission, Washington, D.C. 1981.

175. Stoeffler, R. C. Additional Research on Instabilities in Atmospheric Flow Systems Associated With Clear Air Turbulence. Rep. K910563-19. United Aircraft Research Laboratories. United Aircraft Corp., East Hartford, CT. 1971.

176. Shapiro, M. A. On the Scale of Atmospheric Motions Within Middle-Tropospheric Frontal Zones. NCAR Cooperative Thesis No. 18. Laboratory of Atmospheric Science, National Center for Atmospheric Research, Boulder, CO. 1969.

177. Orgill, M. M. Critical Review of Wind Tunnel Modeling of Atmospheric Heat Dissipation. BNWL-2221. Battelle Pacific Northwest Laboratories, Richland, WA. 1977.

178. USDA. State of Utah Maps: Normal October-April Precipitation (1931-1960), Normal May-September Precipitation (1931-1960), and Normal Annual Precipitation (1931-1960), Utah State Engineer, Office of Utah Water and Power Board, Salt Lake City, Utah. 1965.

179. Katterson, A. M. and P. E. Gallagher. Screening Analysis of Ambient Air Quality Impact from Oil Shale Development in Western Colorado. Rep. No. 560RM165, Gulf Sci. and Tech. Co., Pittsburgh, PA. 1981.

180. Drake, R. L. and C. H. Huang. Western Oil Shale Development: A Technology Assessment. Vol. 3. Air Quality Impacts. PNL-3830-3, Pacific Northwest Laboratory, Richland, WA. 1981.

181. Williams, M. D. and C. A. Mangeng. Local Air Quality in the Four Corners Study Region. National Commission on Air Quality, Washington, D.C. 1980.

182. Rio Blanco Oil Company. Scope of Work Modular Development Phase Environmental Monitoring Program Tract C-a Oil Shale Lease. Rio Blanco Oil Company, Aurora, CO. 1981.

183. Drake, R. L., *et al*. The Green River Ambient Model Assessment Program: A Progress Report for the Regional and Mesoscale Flow Modeling Components. PNL-3988. Pacific Northwest Laboratory, Richland, WA. 1981.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

184. Whiteman, C. D., et al. The Green River Ambient Model Assessment Program: Meteorological Data Report for Special Studies Conducted in August, 1980 in the Oil Shale Region of Northern Colorado. PNL-3734. Pacific Northwest Laboratory, Richland, WA. 1981.

185. Whiteman, C. D. and R. L. Drake. The Green River Ambient Model Assessment Program: Progress Report on Local Scale Modeling Activities. PNL-4058. Pacific Northwest Laboratory, Richland, WA. 1981.

186. Drake, R. L., et al. The Green River Ambient Model Assessment Program: September 1981 Progress Report for Mesoscale Air Quality Modeling. PNL-4060. Pacific Northwest Laboratory, Richland, WA. 1981.

187. EG&G. Upper Air Studies for Federal Oil Shale Tract C-a: Spring 1975. ECR-75-004. EG&G, Environmental Consultants, Denver, CO. 1975.

188. EG&G. Upper Air Comparison Studies Between Oil Shale Tracts C-a, C-b and Grand Junction, Colorado, Summer 1975. ECR-75-017. EG&G Environmental Consultants, Denver, CO. 1975.

189. EG&G. SF_6 Tracer Gas Study for Federal Oil Shale Tract C-a During October 1976. B-4479. EG&G Environmental Consultants, Waltham, MA. 1977.

190. Coffey, M. E., et al. Analysis and Interpretation of the Rio Blanco Oil Shale Tracer Study. NUS-TM-309. NUS Corp., Rockville, MD . 1977.

191. Renne, D. S. A Comparison of Atmospheric Stability Between a Valley and Mountain Site. PNL-SA-6578. Pacific Northwest Laboratory, Richland, WA. 1978.

192. VTN. Final Environmental Baseline Report: Federal Prototype Oil Shale Leasing Program - Tracts U-a and U-b. Utah-White River Shale Project. VTN Colorado, Inc., Denver, CO. 1977.

193. NOAA. Climatological Data, Annual Summary, Utah and Colorado. National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, N.C. 1976.

194. Fosdick, G. E., et al. Air Quality on the Prototype Oil Shale Leasing Program at the Colorado C-b Tract. No. 77-37.4. Pres. at 70th Annual APCA Meeting, June 20-24, 1977, Toronto, Canada. 1977.

195. Occidental Oil. 1978 C-b Annual Report, Vol. 2, Environmental Analysis. C-b Shale Oil Project, Occidental Oil Shale, Inc., Grand Junction, CO. 1979.

196. Occidental Oil. 1979 C-b Annual Report, Vol. 2, Environmental Analysis. Occidental Oil Shale, Inc., Grand Junction, CO. 1980.

197. Latimer, D. A. and J. R. Doyle. Prevention of Significant Deterioration Policy Implications for Projected Oil Shale Development. Draft Final Report. U. S. Environmental Protection Agency, Washington, D.C. 1981.

198. Meyer, L. and R. Nelson. "Adequacy of Regional Atmospheric Data for Specific Predictive Purposes in the Piceance Creek Basin." Proc. of the Environ. Oil Shale Sym. Vol. 70 . No. 4 . 1975. pp. 207-222.

199. Nelson, R. "Meteorological Dispersion Potential in the Piceance Creek Basin." Proc. of the Environ. Oil Shale Sym. Vol. 70 . No. 4. 1975. pp. 223-237.

200. Whiteman, C. D. Breakup of Temperature Inversions in Colorado Mountain Valleys. Atm. Sci. Paper No. 328, Climatology Rep. No. 80-2. Dept. of Atm. Sci., Colorado State University, Fort Collins, CO. 1980.

201. Slinn, W. G. N., M. A. Wolf, and T. P. Hennessey, Jr. Critique of the Meteorological and Air Quality Baseline Monitoring Program for the Prototype Oil Shale Leaseholds. RLO-2227-T31-4. Air Resources Center, Oregon State University, Corvallis, Oregon. 1978.

202. Slinn, W. G. N. Analyses of Air Quality and Meteorological Baseline Data from Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-2227-T31-3. Progress Report No. 1. Air Resource Center, Oregon State University, Corvallis, Oregon. 1978.

203. Wolf, M. A. An Analysis of Baseline Data From Federally Leased Oil Shale Tracts in Colorado and Utah. RLO-227-T31-5. Air Resources Center, Oregon State University, Corvallis, OR. May 1980.

204. Interagency Task Force on Oil Shale. Project Independence Blueprint, Final Task Force Report, Potential Future Role of Oil Shale Prospects and Constraints. Federal Energy Administration, Washington, D.C. 1974.

205. Wolf, M. A., et al. Parachute Creek Valley Diffusion Experiments. Final Report to Colony Development Operation. Pacific Northwest Laboratory, Richland, Washington 1972.

206. Wolf, M. A., et al. Atmospheric Dispersion of Airborne Effluents from the Roan Plateau. Volume 1 and 2. Final Report to Colony Development Operation. Pacific Northwest Laboratory, Richland, Washington. 1973.

207. Bander, T. J. and M. A. Wolf. Transport and Diffusion of Airborne Pollutants Emanating from a Proposed Shale Oil Production Plant. Supplemental Report to Colony Development Operation, Pacific Northwest Laboratory, Richland, Washington, 1975.

208. Chan, M. W. and I. Smith. Report on Tracer Study at Federal Prototype Oil Shale Lease Tract C-b in Rio Blanco, Colorado. AV-R-8172. Aerovironment, Inc., Pasadena, CA, 1978.

209. Anderson, G. E., et al. Air Quality Impacts of Anticipated Development in Oil Shale Operations in Western Colorado and Eastern Utah. SAI No. 155-EF80-147, Systems Applications, Inc., San Rafael, CA. August 1980.

210. Zannetti, P. "An Improved Puff Algorithm for Plume Dispersion Simulation." J. Appl. Meteor. 20. 1981. pp. 1203-1211.

211. Barr, S. and W. E. Clements. Nocturnal Wind Characteristics in Hight Terrain of the Piceance Basin, Colorado. LA-UR-81-1929. Los Alamos Scientific Laboratory, Los Alamos, NM. 1981.

212. Fabrick, A. J. and P. J. Haas. "Analysis of Dispersion Models Used for Complex Terrain Simulation." Proc. Sym. on Intermediate Range Atm. Transport Processes and Tech. Assess. CONF-801064. U. S. Dept. of Energy, Oak Ridge Nat. Lab., Oak Ridge, TN. 1981.

213. Hansen, A. G. and J. E. Cermak. Project Themis: Technical Report No. 29, Vortex-Containing Wakes of Surface Obstacles. CER75-76ACH-JEC16. Fluid Dynamics and Diffusion Laboratory. College of Engineering, Colorado State University, Fort Collins, CO. 1975.

214. Hatcher, R. V., et al. Dispersion in the Wake of a Model Industrial Complex. CER76-77RVH-RNM-JAP-KK35. Fluid Dynamics and Diffusion Laboratory. College of Engineering, Colorado State University, Fort Collins, CO. 1977.

215. Segal, M., et al. "A Numerical Model Study of Plume Fumigation During Nocturnal Inversion Break-Up." Accepted by Atm. Environ. Dept. of Environ. Sci., Univ. of Virginia, Charlottesville, Virginia. 1981.

216. McNider, R. T. and R. A. Pielke. "Diurnal Boundary-Layer Development over Sloping Terrain." J. Atm. Sci. 38. 1981. pp. 2198-2212.

217. McCumber, M. C. and R. A. Pielke. "Simulation of the Effects of Surface Fluxes of Heat and Moisture in a Mesoscale Numerical Model: 1. Soil Layer." J. Geophys. Res. 86. 1981. pp. 9929-9938.

EPA Form 2350-4 (4-80)
(PREVIOUSLY EIN. EPA FORM 237)
TYPING GUIDE SHEET

218. Pielke, R. A. and C. L. Martin. "The Derivation of a Terrain - Following Coordinate System for Use in a Hydrostatic Model." J. Atm. Sci. 38. 1981. pp. 1707-1713.

219. Whiteman, C. David. "Breakup of Temperature Inversions in Deep Mountain Valleys: Part I. Observations." J. of Appl. Meteor. Vol. 21. 1982. pp. 270-289.

220. Whiteman, C. David and Thomas B. McKee. "Breakup of Temperature Inversions in Deep Mountain Valleys: Part II. Thermodynamic Model." J. of Appl. Meteor. Vol. 21. 1982. pp. 290-302.

221. McKee, T. B. and C. D. Whiteman. Components of Infrared Net Radiation in a Mountain Valley. Atmos. Sci. Paper No. 279. Dept. of Atm. Sci., Colorado State Univ., Fort Collins, CO. 1977.

222. Whiteman, C. D. and T. B. McKee. "Air Pollution Implications of Inversion Descent in Mountain Valleys." Atmos. Environ. 12. 1978. pp. 2151-2158.

223. Whiteman, C. D. and T. B. McKee. Temperature Inversion Destruction in Mountain Valleys--Implications for Air Pollution Dispersion. Pres. at NATO/CCMS Air Pollution Pilot Study, 10th International Tech. Meeting on Air Pollution Modeling and Its Application, Rome, Italy. October 23-26, 1979.

224. Runca, E., P. Melli and P. Zannetti. Computation of Long-Term Average SO_2 Concentration in the Venetian Area. Appl. Math. Model. 1. 1976. pp. 9-15.

225. Zannetti, P., P. Melli, and E. Runca. "Meteorological Factors Affecting SO_2-Pollution Level in Venice." Atmospheric Environment. 11. 1977. pp. 605-616.

226. Zannetti, P., *et al*. AVACTA II: User's Guide - Release 1. AV-FR-81/598. AeroVironment, Inc., Pasadena, CA. 1981.

227. Changery, M. J., W. T. Hodge and J. V. Ramsdell. Index-Summarized Wind Data. BNWL-2220 WIND-11, NOAA/Pacific Northwest Laboratory. National Climatic Center, Asheville, North Carolina. 1977.

228. Lee, H. N. and S. K. Kao. "Finite Element Numerical Modeling of Atmospheric Turbulent Boundary Layer." J. of Appl. Meteor. 18. 1979. pp. 1287-1295.

229. Venkatram, A. "A Model of Internal Boundary Layer Development." Boundary-Layer Meteorology. 11. 1977. pp. 419-437.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

230. Venkatram, A. "Estimating the Monin-Obukhov Length in the Stable Boundary Layer for Dispersion Calculations." Boundary-Layer Meteorology. 19. 1980. pp. 481-485.

231. Thornton, E. A., et al. A Computer Graphics Program for General Finite Element Analyses. Old Dominion Univ., Research Foundation. (NASA CR 157421). Aug. 1978.

232. Speelpenning, B. Generalized Element Method. COO-2383-0055. Illinois Univ.,Urbana, IL. Dept. of Computer Science. Nov. 1978.

233. Schatzmann, M. Buoyant Jets in Natural Flows: Development of a Mathematical Model. ANL-Trans-1187. Karlsruhe Univ. (TH). Germany, F.R. Oct. 1977.

234. Pepper, D. W. and C. D. Kern. Modeling the Dispersion of Atmospheric Pollution Using Cubic Splines and Chapeau Functions. DP-MS-76-83. DuPont de Nemours and Co., Aiken, S.C. Savannah River Lab. 1977.

235. Gartling, D. K. Finite Element Analysis of Several Standard Flow Problems. SAND-78-1360C. Rutgers-the State Univ., New Brunswick, N.J. 1978.

236. Blottner, F. G. Variable Grid Scheme for Discontinuous Grid Spacing and Derivatives. SAND-79-0209C. Sandia Labs., Albuquerque, N.M. 1979.

237. Davis, C. G. and B. E. Freeman. Comparison of a Drainage Flow Model With The Data of Manins & Sawford. LA-UR-81-1932. Los Alamos National Lab., N.M. 1981.

238. Davis, C. G. Nocturnal Drainage Flow Over Complex Terrain Using a Generalized Shallow-Fluid Approximation. LA-UR-81-2087. Los Alamos National Lab.,N.M. 1981.

239. Shinn, J. M. and R. T. Cederwall. Observed Turbulence Intensities in a Desert Boundary Layer. UCRL-94672. Lawrence Livermore National Lab.,CA. Oct. 1980.

240. Murphy, B. D. Phenix: A Pseudo-Spectral Model of Long-Range Atmospheric Transport. ORNL-5761. Oak Ridge National Lab., TN. July 1981.

241. Protocol for Plume Model Validation. Final Report. EPRI-EA-1638. TRC Environmental Consultants, Wethersfield, CT. 1980.

242. Bowne, N. E. and R. J. Londergan, et al. Preliminary Results From The EPRI Plume Model Validation Project: Plains Site. EPRI-EA-1788. TRC Environmental Consultants, Wethersfield, CT. April 1981.

243. Budney, L. J. Guidelines for Air Quality Maintenance Planning and Analysis Volume 10 (Revised): Procedures for Evaluating Air Quality Impact of New Stationary Sources. EPA-450/4-77-001. U. S. EPA , Research Triangle Park, N.C. 1977.

244. U. S. EPA. OAQPS Guideline Series: Guideline on Air Quality Models. U. S. EPA , Research Triangle Park, N.C. 1980.

245. Turner, D. B. and A. D. Busse. UNAMAP (Version 4), User's Network for Applied Modeling of Air Pollution. EPA/DF-81/001. U. S. EPA , Research Triangle Park, N.C. 1981.

246. Patnaik, P. C. Preliminary User's Guide for the SIGMET Mesoscale Meteorology Code. Special Report (DOE/ET/20280-2). Science Applications, Inc., LaJolla, CA. 1979.

247. Traci, R. M., et al. Sample Dispersion Simulations Using the CONCORD Dispersion Model. Science Applications, Inc., LaJolla, CA. 1981.

248. Bass, A., et al. Project Summary: Potential Flow Model for Gaussian Plume Interaction With Simple Terrain Features. EPA-600/54-81-008. U. S. EPA, Research Triangle Park, N.C. 1981.

249. Bird, R. and R. Hulstrom. Application of Monte Carlo Techniques to Insolation Characterization and Prediction. Status Report. 1 October 1978 - 1 June 1979. SERI/RR-36-306. Solar Energy Research Institute, Golden, CO. 1979.

250. Omstedt, G. Parameterization of Vertical Diffusion in a Diurnally Varying Boundary Layer. Rep. No. 27. Dept. of Meteorology, Univ. of Stockholm, Stockholm, Sweden. 1979.

251. Lupini, R. and T. Tirabassi. "Gaussian Plume Model and Advection - Diffusion Equation: An Attempt to Connect the Two Approaches." Atmos. Environ. 13. 1979. pp. 1169-1174.

252. Choudhury, B. J. and A. T. C. Chang. "The Albedo of Snow for Partially Cloudy Skies." Boundary-Layer Meteorology. 20. 1981. pp. 371-389.

253. Spera, D. A. and T. R. Richards. Modified Power Law Equations for Vertical Wind Profiles. DOE/NASA/1059-79/4. Lewis Research Center. NASA, Cleveland, Ohio. 1979.

254. Oliver, D. A., et al. "The Interaction Between Turbulent and Radiative Transport in the Development of Fog and Low-Level Stratus." J. of Atmos. Sci. 35. 1978. pp. 301-316.

255. Lenschow, D. H., et al. "The Rapid Morning Boundary-Layer Transition." J. of Atm. Sci. 36. 1979. pp. 2108-2124.

256. Lenschow, D. H. and P. L. Stephens. "The Role of Thermals in the Convective Boundary Layer." Boundary-Layer Meteorology, 19. 1980. pp. 509-532.

257. Mahrt, L. "Modeling the Depth of the Stable Boundary Layer." Boundary-Layer Meteorology, 21. 1981. pp. 3-19.

258. Antonia, R. A., *et al*. "Temperature Structure in the Atmospheric Surface Layer: II. The Budget of Mean Cube Fluctuations." Boundary-Layer Meteorology. 20. 1981. pp. 293-307.

259. Houghton, J. G. "A Model for Orographic Precipitation in the North-Central Great Basin." Monthly Wea. Rev. 107. 1979. pp. 1462-1475.

260. Banta, R. and W. R. Cotton. A Diagnostic Parameterization for Subgrid Covariances in a Boundary-Layer Model. Pres. at 4th Conf. on Numerical Weather Prediction, held at Silver Spring, MD., 29 Oct.-1 Nov. 1979. Sponsored by Amer. Meteor. Soc. 1979.

261. Gifford, F. A. Horizontal Diffusion in the Atmosphere: A Lagrangian-Dynamical Theory. LA-8667-MS. Los Alamos Nat. Lab., Los Alamos, N.M. 1981.

262. Anthes, A. and T. T. Warner. "Development of Hydrodynamic Models Suitable for Air Pollution and Other Mesometeorological Studies." Monthly Wea. Rev. 106. 1978. pp. 1045-1078.

263. Andreev, V. and K. Gannev. "Model of Convective Heat Exchange due to Isolated Thermals in the Atmospheric Boundary Layer." Boundary-Layer Meteorology. 20. 1981. pp. 331-339.

264. Carpenter, K. M. "An Experimental Forecast Using a Non-Hydrostatic Mesoscale Model." Quart. J. R. Met. Soc. 105. 1979. pp. 629-655.

265. Bradley, E. F., *et al*. "Temperature Structure in the Atmospheric Surface Layer: I. The Budget of Temperature Variance." Boundary-Layer Meteorology. 20. 1981. pp. 275-292.

266. Goodin, W. R., *et al*. An Objective Analysis Technique for Constructing Three-Dimensional, Urban-Scale Wind Fields. Environ. Quality Lab., Cal. Tech., Pasadena, CA. 1980.

267. Gedayloo, T., *et al*. Nocturnal Drainage Wind Characteristics in Two Converging Air Sheds. LA-UR-80-805. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1980.

268. Janour, Z. and D. Yordanov. "On the Resistence Low for the Non-stationary Atmospheric Boundary Layer." Boundary-Layer Meteorology. 20. 1981. pp. 269-273.

269. Manins, P. C. and B. L. Sawford. "A Model of Katabatic Winds." J. of Atm. Sci. 36. 1979. pp. 619-630.

270. Nieuwstadt, F. T. M. "The Steady-State Height and Resistance Laws of the Nocturnal Boundary Layer: Theory Compared With Cabauw Observations." Boundary-Layer Meteorology. 20. 1981. pp. 3-17.

271. Peterson, R. A. and L. W. Uccellini. "The Computation of Isentropic Atmospheric Trajectories Using a "Discrete Model" Formulation." Monthly Wea. Rev. 107. 1979. pp. 566-574.

272. Rooney, D. M. and G. S. Janowitz. "Flow over the Rocky and Andes Mountains: Application of an Analytical Method." J. of Atm. Sci. 36. 1979. pp. 549-558.

273. Smith, R. B. "Some Aspects of the Quasi-Geostraphic Flow over Mountains." J. of Atm. Sci. 36. 1979. pp. 2385-2393.

274. Seaman, N. L. and R. A. Anthes. "A Mesoscale Semi-Implicit Numerical Model." Quart. J. R. Met. Soc. 107. 1981. pp. 167-190.

275. Thompson, N. "Turbulence Measurements Above a Pine Forest." Boundary-Layer Meteorology. 16. 1979. pp. 293-310.

TABLE B-2d. REFERENCES ON GASEOUS REACTIONS, PHOTOCHEMISTRY, GAS-TO-PARTICLE CONVERSIONS AND AEROSOL DYNAMICS (CHEMISTRY) TOPICS

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Chemistry	1	X			X	X	X		X	X			Aerosol Model User's Manual
	2	X				X	X		X	X			Aerosol and Visibility Measurements
	3	X				X	X		X	X			Tropospheric Airborne Chemistry Measurements
	4	X					X	X	X	X			Non-Urban Aerosols (field)
	5		X		X	X	X		X	X			CCNs in Coal-Fired Plumes
	6		X		X	X	X		X	X			CCNs, SO_x, NO_x in Plumes
	7	X				X	X			X	X		Photochemistry (research project)
	8	X				X	X			X	X		Heterogeneous Oxidation of SO_2 (research project)
	9	X				X	X			X	X		NO_x/O_x Chemistry (research project)
	10	X			X	X	X		X	X	X		Lab, Model, Aerosol Dynamics (research project)
	11	X			X	X			X	X			Smog Chamber Studies of Diesel Exhaust (research project)
	12	X			X	X			X	X			CCNs in Urban Air and Power Plant Plume (research project)
	13	X				X	X		X	X			CCN Budget in Power Plant Plumes (research project)
	14	X				X	X			X	X		Rural Oxidant Field Studies (research project)
	15	X			X	X			X	X	X		Smog Chamber Studies of Aged Smog (research project)
	16	X			X	X				X	X		Field and Modeling, Aerosols
	17	X			X	X			X	X			Particles in Plumes, CCN (research project)

(continued)

TABLE B-2d. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Chemistry	18	X			X	X			X	X			Sulfur and Nitrogen Chemistry (research project)
	19	X				X	X	X	X	X	X		Aerosol Physics and Chemistry (research project)
	20	X			X	X	X		X	X	X		Halogenated HCs; Urban, Rural, Marine; Field and Model (research project)
	21	X				X				X	X		Role and Particles in Urban A.Q. (research project)
	22	X			X	X			X	X			Trace Elements From Combustion (research project)
	23	X			X	X			X	X			Smog Chamber Tests, Mutagenic Compounds (research project)
	24	X				X				X	X		Fate of NO_x in Urban Air (research project)
	25	X				X	X			X	X		Fate of NO_x in Rural Areas (research project)
	26	X				X	X			X	X		Stratospheric Ozone in Urban Air (research project)
	27	X			X	X			X	X	X		Smog Chamber Exp. of Aged Smog (research project)
	28	X				X	X		X	X			Theoretical Studies in Aerosol Dynamics (research project)
	29	X			X	X			X	X			Laboratory and Modeling Studies of HC/NO_x Chemistry (research project)
	30	X				X	X			X	X		Field Investigation of Atmospheric Aerosol (research project)

(continued)

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TABLE B-2d. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Chemistry	31	X			X	X			X	X			Field and Lab. Studies of Gas-to-Particle Conversions (research project)
	32	X			X	X			X	X			CCN Budget From Power Plant Plumes (research project)
	33	X			X	X			X	X			CCN Budget, Lab and Field Work (research project)
	34	X				X	X			X	X		Cloud Cover versus Photodis-association of NO_x (research project)
	35	X				X	X				X	X	Role of Aerosols in Climate (research project)
	36	X				X	X			X	X		Aerosol Composition Data (field and model)
	37	X				X	X			X			Field Comparison of Polluted and Clean Air Masses
	38	X				X	X			X			Acidity in Atmospheric Aerosols
	39	X				X	X		X	X	X		Environmental Chemistry at BNL (research project)
	40	X			X	X			X	X			Studies of Aqueous Phase SO_2 Chemistry (research project)
	41	X			X	X	X		X	X			SO_2-Photochemistry Model (research project)
	42	X			X	X			X	X			Field Study of Plume Conversion Rates (research project)
	43	X			X	X			X	X			Aerosol Particle Interactions (research project)

(continued)

TABLE B-2d. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Chemistry	44	X			X	X			X	X			SO_2 Oxidation in Power Plant Plumes (research project)
	45	X			X	X			X	X			Model of Stack Plume Reactions (research project)
	46	X			X	X			X	X			Lab Studies of Plume Organic Chemistry (research project)
	47	X			X	X			X	X			Theoretical Studies of Aerosol Collision and Nucleation (research project)
	48	X			X	X			X	X			Sampling of Power Plant Plumes (research project)
	49	X			X	X	X		X	X			Model of $HC/SO_2/O_x$ Chemistry (research project)
	50	X			X	X			X	X			SO_x and NO_x Aqueous Phase Chemistry (research project)
	51	X			X	X	X		X	X	X	X	Summary Reports on NO_x, O_3, O_x
	52	X			X	X	X		X	X	X	X	Summary Report on SO_x
	53	X			X	X	X		X	X	X	X	Summary Reports on H_2S, Ammonia, Particles
	54	X			X	X	X	X	X	X	X	X	Summary Reports on Odors, CO_2
	55		X				X				X	X	Stratospheric Ozone From Low Pressure Systems
	56			X	X	X				X	X		Environmental Monitoring of Air Quality
	57	X				X	X			X	X		CCN Produced by Coal Development
	58	X	X					X				X	Global Air Pollution and Climate

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TABLE B-2d. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Chemistry	59	X			X	X	X	X	X	X	X		Particle Morphology
	60	X					X	X			X	X	Stratospheric Ozone and Man
	61	X			X	X	X			X	X		TSP Distribution Functions
	62	X			X	X			X	X			CCN From Power Plant Plumes
	63		X			X	X			X	X		Background Ozone Levels
	64	X			X	X			X	X			NO_x Emissions versus NO_2 Air Quality
	65	X			X	X			X	X			Photochemical Model
	66			X	X	X			X	X	X		Air Quality Monitoring Near Rock Springs, Wyoming
	67	X			X	X	X		X	X	X		Interpolation Techniques
	68	X			X	X			X	X			Homogeneous Oxidation of SO_2 in Cloud Droplets
	69	X			X	X	X		X	X			Homogeneous Oxidation of SO_2
	70	X			X	X	X		X	X			Model Performance Package
	71	X						X		X	X		Regional SO_2 to Sulfate Model
	72		X				X	X		X	X		Characterization of Particles in the Arid West
	73	X			X	X			X	X			Particles in Power Plant Plumes (field)
	74	X			X	X			X	X			Effects of Power Plants on the Atmosphere Aerosol
	75			X	X	X			X	X			Organic Species Emitted From Oil Shale Conversion
	76	X			X	X	X		X	X			SO_2 to Sulfate Conversion Rates
	77	X				X	X			X	X		Compounds in Atmosphere Aerosols
	78	X			X							X	Computerized Chemical Dictionary

(continued)

TABLE B-2d. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Chemistry	79	X			X	X			X	X			Integration of Stiff Systems
	80	X			X	X			X	X			Integration of Stiff Systems
	81	X			X	X			X	X			Integration of Stiff Systems
	82	X			X	X			X	X			Integration of Stiff Systems
	83	X			X	X			X	X			Integration of Stiff Systems
	84	X			X	X			X	X			Integration of Stiff Systems
	85	X			X	X			X	X			Integration of Stiff Systems
	86	X			X	X	X		X	X	X		Chemicals in the Atmosphere
	END	-	-	-	-	-	-	-	-	-	-	-	----

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TYPING GUIDE SHEET

REFERENCES

d. Chemistry

1. Gelbard, F. Aerosol Users Manual. NUREG/CR-1367 & SAND 80-0403. Sandia National Laboratories, Albuquerque, N.M. 1980.

2. Alkezweeny, A. J. and C. M. Berkowitz. Visibility and the Chemical Composition of Aerosols in Air Masses over Lake Michigan. Pacific Northwest Laboratory, Richland, WA. 1981.

3. Delany, A. C. and J. W. Winchester (Editors). Tropospheric Chemistry: Measurements from Aircraft Atmospheric Technology. No. 12. National Center for Atmospheric Research, Boulder, CO. 1980.

4. Alkezweeny, A. J. and N. S. Laulainen. Chemical Composition of Non-Urban Aerosol. Pres. at 2nd Symp. on the Composition of the Non-Urban Troposphere held at Williamsburg, VA. 25 May 1982. 1982.

5. Pueschel, R. F., et al. Environmental Effects of Pollutants from Coal Combustion: 1. The Four Corners Power Plant, Farmington, N.M. NOAA-81062608. National Oceanic and Atmospheric Administration, Boulder, CO. 1981.

6. Van Valin, C. C., et al. Environmental Effects of Pollutants from Coal Combustion: 2. The Coalstript, Montana Power Plant. NOAA-81062609. National Oceanic and Atmospheric Administration, Boulder, CO. 1981.

7. Mendenhall, G. D. Isotopic Labeling Techniques to Study the Photooxidations of Hydrocarbons in Air. SSIE No. DI-970-1. U. S. National Science Foundation, Washington, D.C. 1981.

8. Harrison, H. Heterogeneous Oxidation of Sulfur in the Atmosphere. SSIE No. DN-1018-1. U. S. Dept. of Energy, Washington, D.C. 1981.

9. Spicer, C., et al. Fate of NO_x and Transport of Oxidant SSIE No. GMA-3126-Z. U. S. EPA, Research Triangle Park, N.C. 1981.

10. Brock, J. R. Aerosol Dynamics. SSIE No. GMA-3880-1. U. S. EPA, Research Triangle Park, N.C. 1981.

11. Anderson, R. Diesel Exhaust Chamber Studies-Incremental Funding. SSIE No. GMA-5803-1. U. S. EPA, Research Triangle Park, N.C. 1981.

12. Saxena, V. K. Impact of Gaseous Sulfur and Aerosols Produced by Power Plants on the CCN Budget. SSIE No. ER-798. U. S. Dept. of Energy, Germantown, MD. 1981.

13. Saxena, V. K. Impact of Gaseous Sulfur and Aerosols Produced by Power Plants on the CCN Budget. SSIE No. ER-956. U. S. Dept. of Energy, Germantown, MD. 1981.

14. Westberg, H. Rural Oxidant Studies and the Role of NO_x in Rural Oxidation Formation. SSIE No. GMA-5796. U. S. EPA, Research Triangle Park, N.C. 1981.

15. Jeffries, H. E. and R. M. Kamens. Outdoor Simulation of Air Pollution Control Strategies. SSIE No. GMA-5982-1. U. S. EPA, Research Triangle Park, N.C. 1981.

16. Myrup, L. O., et al. Urban and Rural Environmental Quality Protection. SSIE No. GY-66897-5. U. S. Dept. of Agriculture, Berkeley, CA. 1981.

17. Pueschel, R. F. Atmospheric Chemistry. SSIE No. ZBP-1328-3. U. S. Dept. of Commerce, Boulder, CO. 1981.

18. Newman, L. Atmospheric Diagnostics. SSIE No. ZPE-10627-6. U. S. Dept. of Energy, Germantown, MD. 1981.

19. Kneip, T. J. and P. J. Lioy. Urban and Rural Characteristics, Source-Transport Studies. SSIE No. 1ES-2099-1. U. S. Dept. of Health and Human Services, Research Triangle Park, N.C. 1981.

20. Bufalini, J. Management and In-House Research on Chemistry and Persistence of Toxics in Air. SSIE No. ZMA-1940. U. S. EPA, Research Triangle Park, N.C. 1981.

21. Novakov, T. The Role of Primary Particulates in Urban Air Pollution. SSIE No. GSQ-1864-3. U. S. NSF, Washington, D.C. 1981.

22. Gordon, G. E. Sources, Transformation, and Chemical Nature of Atmospheric Pollutants. SSIE No. GSQ-1669-3. U. S. NSF, Washington, D.C. 1981.

23. Pitts, J. N. Atmospheric Transformations and Mutogenic Activity of Primary and Secondary Air Pollutants. SSIE No. GSQ-798-5. U. S. NSF, Washington, D.C. 1981.

24. Spicer, C. Fate of NO_x in the Atmosphere. SSIE No. GMA-5807. U. S. EPA, Research Triangle Park, N.C. 1981.

25. Westberg, H. Rural Oxidant and the Role of NO_x in Rural Oxidation Formation. SSIE No. GMA-5796. U. S. EPA, Research Triangle Park, NC. 1981.

26. Husain, L. Stratospheric Ozone in Urban Air. SSIE No. GMA-5215-Z. U. S. EPA, Research Triangle Park, N.C. 1981.

EPA Form 2350-4 (4-80)
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TYPING GUIDE SHEET

27. Jeffries, H. E. and R. Kamens. Outdoor Simulation of Air Pollution Control Strategies. SSIE No. GMA-5172-1. U. S. EPA, Research Triangle Park, N.C. 1981.

28. Brock, J. R. Theoretical Studies of Aerosol Dynamics. SSIE No. GMA-3880-2. U. S. EPA, Research Triangle Park, N.C. 1981.

29. O'Brien, R. J. An Investigation of the Reactions of Aromatic Hydrocarbons in Photochemical Air Pollution. SSIE No. GMA-3864-3. U. S. EPA, Research Triangle Park, N.C. 1981.

30. Whitby, K. T. Formation of Atmospheric Aerosols. SSIE No. GMA-2528-4. U. S. EPA, Research Triangle Park, N.C. 1981.

31. Durham, J. L. Dynamics and Kinetics of Aerosol Pollutants. SSIE No. GMA-2477-4. U. S. EPA, Research Triangle Park, N.C. 1981.

32. Saxena, V. K. Impact of Gaseous Sulfur and Aerosols Produced by Power Plants on the CCN Budget. SSIE No. ER-956. U. S. Dept. of Energy, Germantown, MD. 1981.

33. Tang, I. N. Aerosol Chemistry and Dynamics. SSIE No. ER-92. U. S. Dept. of Energy, Germantown, MD. 1981.

34. Miksad, R. W. and F. L. Jones. Correlation of NO_2 Photodissociation Rates with Solar Radiation Data. SSIE No. NTX-2036. Univ. of Texas, Austin, Texas. 1981.

35. Russell, P. B. and E. E. Uthe. Study of Aerosol Effects on Solar Radiation Using LIDAR and on Instrumented Tower. SSIE No. DV-916-1. U. S. NSF, Washington, D.C. 1981.

36. Zinsmeister, A. R. "A Time Series Analysis of Aerosol Composition Data." Atmos. Environ. 14. 1980. pp. 201-215.

37. Alkezweeny, A. J. and N. S. Laulainen. "Comparison Between Polluted and Clean Air Masses Over Lake Michigan." J. Appl. Meteor. 20. 1981. pp. 209-212.

38. Tanner, R. L., et al. "Acidity in Atmospheric Aerosols." Environ. Sci. & Tech. 15. 1981. pp. 1150-1153.

39. Newman, L. Environmental Chemistry Division Annual Report - 1980. BNL-29528 (Informal Report). U. S. DOE, Brookhaven National Laboratory, Upton, N.Y. 1980.

40. Schwartz, S. E. and J. E. Freiberg. Mass-Transport Limitations to the Rate of Reaction of Gases in Liquid Droplets: Application to Oxidation of SO_2 in Aqueous Solutions. U. S. DOE. BNL-27727. Brookhaven National Laboratory, Upton, N.Y. 1980.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

41. Levine, S. Z. and S. E. Schwarz. Construction and Testing of a Surrogate Chemical Mechanism (SCHEME) for Tropospheric Photochemical Reactions. BNL-27733. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

42. Garber, R. W., et al. Conversion Rates in Power Plant Plumes Based on Filter Pack Data Part II: The Oil Fired Northport Plume. BNL-28349. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

43. Marlow, W. H. Size Effects in Aerosol Particle Interactions: The Van der Waals Potential and Collision Rates. BNL-28348. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

44. Newman, L. Atmospheric Oxidation of Sulfur Dioxide as Viewed from Power Plant and Smelter Plume Studies. BNL-28347. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

45. Levine, S. Z. A Model for Stack Plume Reactions with Atmospheric Dilutions (SPREAD). BNL-28332. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

46. Gaffney, J. S. and S. Z. Levine. Kinetics and Mechanisms of Organic Air Pollutants. BNL-27886. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

47. Marlow, W. H. Lifshitz - Van der Waals Forces in Aerosol Collisions and Nucleation. BNL-27880R. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

48. Dietz, R. N. and R. W. Garber. Power Plant Flue Gas and Plume Sampling Studies: Progress Report No. 3, August 1978 - July 1979. BNL-27855. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

49. Levine, S. Z. and J. S. Gaffney. Modeling Atmospheric Ozone and Sulfate Formation in the Presence of Reactive Natural Hydrocarbon Emissions. BNL-27872. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

50. Schwartz, S. E. Incorporation of Acids into Cloud Water. (EPRI Project) Brookhaven National Laboratory, Upton, N.Y. 1980.

51. National Research Council. Reports on: (1) Nitrogen Oxides; (2) Ozone and Other Photochemical Oxidants; and (3) Environmental Monitoring. National Academy of Sciences Studies, Washington, D.C. 1977.

52. National Research Council. Sulfur Oxides. National Academy of Sciences, Washington, D.C. 1978.

53. National Research Council. (1) Hydrogen Sulfide; (2) Ammonia and (3) Airborne Particles. University Park Press, Baltimore, MD. 1979.

54. National Research Council. (1) Odors from Stationary and Mobile Sources, and (2) Carbon Dioxide and Climate: A Scientific Assessment. National Academy of Sciences Studies, Washington, D.C. 1979.

55. Palmer, T. Y. "Downward Transport of Stratospheric Ozone from a Cold Low During a Heavy Sierra Nevada Snow Storm." Symp. on Sierra Nevada Meteorology. Held at South Lake Tahoe, CA. June 19-21, 1978. Sponsored by Amer. Meteor. Soc. 1978. pp. 23-28.

56. Virgona, J. E., et al. Summary of the Environmental Monitoring at the Rock Springs, Wyoming Site No. 9, True In-Situ Oil Shale Retorting Experiment. LETC/RI - 79/03. Laramie Energy Technology Center, Laramie, WY. 1979.

57. Davis, B. L., et al. Ground Level Measurement of Nuclei from Coal Development in the Northern Great Plains: Baseline Measurements. Rep. 78-14. Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, South Dakota. 1978.

58. Bach, W. "Global Air Pollution and Climate Change." Reviews of Geophys. and Space Physics. 14. 1976. pp. 429-474.

59. Beddow, J. K. and T. P. Meloy. Advanced Particulate Morphology: Theory and Practice. CRC Press Inc., Boca Raton, Florida. 1980.

60. Bower, F. A. and R. B. Ward. Stratospheric Ozone and Man. Volume I and II. CRC Press Inc., Boca Raton, Florida. 1982.

61. Nevers, N., et al. "Patterns in TSP Distribution Functions." APCA J. 29. 1979. pp. 32-37.

62. Hobbs, P. V., et al. "Cloud-Active Nuclei from Coal-Fired Electric Power Plants and their Interactions with Clouds." J. Appl. Meteor. 19. 1980. pp. 439-451.

63. Hoffer, T. E., et al. Background Continental Ozone Levels in the Rural Southwest Desert. Paper No. 79-52.6. Pres. at 72nd Annual Meeting of APCA at Cincinnati, Ohio. June 24-29, 1979.

64. Keyes, D. L. Characterization of NO_x Emission Sources and Patterns of NO_2 Air Quality. Energy & Environmental Analysis, Inc., Arlington, VA. 1979.

65. McRae, G. J., et al. Development of a Second-Generation Mathematical Model for Photochemical Air Pollution I. Model Formulation. Environ. Quality Lab., California Institute of Technology, Pasadena, CA. 1981.

66. Virgona, J. E., et al. Summary of the Environmental Monitoring at the Rock Springs, Wyoming Site No. 9, True In-Situ Oil Shale Retorting Experiment. LETC/RI-79/03. Laramie Energy Technology Center, Laramie, Wyoming. 1979.

67. Fritsch, F. "Physically Reasonable Interpolation Methods." Energy & Technology Review. Lawrence Livermore National Laboratory, Livermore, CA. 1981. pp. 10-15.

68. Hegg, D. A. and P. V. Hobbs. "The Homogeneous Oxidation of Sulfur Dioxide in Cloud Droplets." Atmos. Environ. 13. 1979. pp. 981-987.

69. Calvert, J. G. "Mechanism of the Homogeneous Oxidation of Sulfur Dioxide in the Troposphere." Atmos. Environ. 12. 1978. pp. 197-226.

70. Bencala, K. E. and J. H. Seinfeld. "An Air Quality Model Performance Assessment Package." Atmos. Environ. 13. 1979. pp. 1181-1185.

71. Carmichael, G. R. Development of a Regional Transport/Transformation/Removal Model for SO_2 and Sulfate in the Eastern United States. Ph.D. Dissertation. Univ. of Kentucky, Lexington, Kentucky. 1979.

72. Flocchini, R. G., et al. "Characterization of Particles in the Arid West." Atmos. Environ. 15. 1981. pp. 2017-2030.

73. Hobbs, P. V., et al. "Evolution of Particles in the Plumes of Coal-Fired Power Plants - I. Deductions from Field Measurements." Atmos. Environ. 13. 1979. pp. 935-951.

74. Wangen, L. E. Relationships Between the Elemental Composition and Particle Sizes of Aerosols With and Without Impact From a Coal-Fired Power Plant. LA-8759-MS. Los Alamos National Lab., N.M. April 1981.

75. Formation and Transformation of Organic Species Emitted From Oil-Shale Conversion. DOE/ER/04960-2. Dept. of Chemistry. Colorado State Univ., Fort Collins, CO. August 1981.

76. Zak, B. D. Lagrangian Measurements of Sulfur Dioxide to Sulfate Conversion Rates. SAND-80-2175. Sandia National Labs., Albuquerque, N.M. May 1981.

77. Lichtman, D. Compound Identification of Atmospheric Particles. Final Report. EPRI-EA-1595. Wisconsin Univ., Milwaukee, WI. October 1980.

78. Kannan, K. L., R. J. Schultheisz, and D. F. Walker. Design and Implementation of an On-Line Chemical Dictionary. (Chemline). CONF-780615-4. Union Carbide Corp., Oak Ridge, TN. Computer Science Div., National Library of Medicine.,Wash. D.C. 1978.

79. Gear, C.W. Future Developments In Stiff Integration Techniques - Stability of Methods That Do Not Use An Exact Jacogian. COO-2383-0035. Univ. of Illinois, Urbana, IL. Dec. 1976.

80. Fatunla, S. O. Numerical Integrators for Stiff and Highly Oscillatory Differential Equations. COO-2383-0044. Dept. of Computer Science. Illinois Univ., Urbana, IL. Oct. 1977.

81. Brown, R. L. On The Stability of Nonlinear Differential Sequences Generated Numerically. NASA CR 157732. Virginia Univ. 9 Oct. 1978.

82. Shampine, L. F. Theory and Practice of Solving Ordinary Differential Equations (ODES). SAND-78-0100. Sandia Labs., Albuquerque, N.M. Apr. 1978.

83. Gear, C. W. Stability of Variable-Step Methods For Ordinary Differential Equations. COO-2383-0048. Dept. of Computer Science. Illinois Univ., Urbana, IL. July 1978.

84. Shampine, L. F. What Everyone Solving Differential Equations Numerically Should Know. SAND-78-0315. Sandia Labs., Albuquerque, N.M. Mar. 1979.

85. Gear, C. W. Runge-Kutta Starters For Multistep Methods. COO-2383-0053. Dept. of Computer Science. Illinois Univ., Urbana, IL. Sept. 1978.

86. Graedel, T.E. Chemical Compounds in the Atmosphere. Academic Press, New York. 1978.

TABLE B-2e. WET AND DRY REMOVAL REFERENCES

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Removal	1	X				X	X			X	X	X	Wet, Dry, Field, Lab, Theory
	2	X						X			X	X	MAP3S/RAINE Precipitation Chemistry Network
	3	X						X			X	X	MAP3S/RAINE Precipiation Chemistry Network
	4	X				X			X	X			Wet Removal of Sulfates
	5	X						X			X	X	MAP3S/RAINE Precipitation Chemistry Network
	6	X					X	X			X	X	Acid Rain Source-Receptor Relationships
	7	X				X	X			X			Sulfate Washout Ratios for Winter Storms
	8	X				X	X			X			Wet Removal of Particles
	9	X					X	X		X	X	X	Precipiation Chemistry and Wet Removal
	10	X			X	X	X		X	X			Scavenging of Nitric Acid Vapor (research project)
	11	X						X			X	X	Dry Deposition Velocity Maps
	12	X			X	X	X		X	X	X		Review of Wet Removal Process
	13	X					X	X		X	X		Oxidation and Scavenging Characteristics of April Rains
	14	X			X	X			X	X			Sulfate Removal via Precipitation
	15	X						X			X	X	SO_2 Deposition by Precipitation
	16	X			X	X			X	X			Concentration of Sulfate in Precipitation
	17	X						X			X	X	SO_2 versus Sulfate Wet Removal
	18	X			X	X			X	X			Model of Dry Removal of Gases
	19	X			X	X	X		X	X			Deposition of SO_2 on Vegetation

(continued)

TABLE B-2e. (Continued)

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Removal	20	X			X	X					X	X	Mercury Residues in Soil
	21	X			X	X			X	X	X		Deposition of Particles in a Plant Canopy
	22	X			X	X			X	X			Washout of Polydisperse Aerosols
	23	X			X	X			X	X			Precipitation Scavenging of Urban Pollutants
	24	X			X	X	X			X	X	X	Conference on Wet and Dry Removal
	25	X			X	X	X			X	X	X	Particle Resuspension: A Review
	26	X			X	X	X			X	X	X	Particles and Gas Dry Deposition
	27	X					X	X		X	X		Comparison of Regional Models
	28	X			X	X	X		X	X	X		Survey of Dry Deposition
	29	X			X	X			X	X			Dry Deposition From Plumes
	30	X				X	X		X	X			Simulation of Rainout
	31	X				X	X	X		X	X		Simulation of SO_2/Sulfate Dry Deposition
	32	X			X	X			X	X			Markov Chain Model of Cloud Sequences
	33	X			X	X			X	X			Surface Fluxes of Air Pollutants (field)
	34	X					X	X		X	X		Wet and Dry Deposited Pollens
	35	X			X	X	X		X	X			Wet and Dry Depsition Over Forests
	36	X			X	X	X	X	X	X	X	X	Workshop on Dry Deposition
	37	X			X	X			X	X			In-Cloud Conversion of SO_2 to Sulfate
	38	X			X	X	X	X	X	X	X	X	Precipitation Chemistry Review
	END	–	–	–	–	–	–	–	–	–	–	–	----

REFERENCES

e. Removal

1. Slinn, W. G. N., et al. Wet and Dry Deposition and Resuspension of AFCT/TFCT Fuel Processing Radionuclides. SR-0980-10. Air Resources Center, Oregon State University, Corvallis, OR. 1979.

2. Dana, M. T. The MAP3S/RAINE Precipitation Chemistry Network: Quality Control. PNL-3612. Pacific Northwest Laboratory, Richland, WA. 1980.

3. Dana, M. T., et al. The MAP3S Precipitation Chemistry Network: Third Periodic Summary Report (July 1978 - Dec. 1979). PNL-3400. Pacific Northwest Laboratory, Richland, WA. 1980.

4. Scott, B. C. "Parameterization of Sulfate Removal by Precipitation." J. of Appl. Meteor. Vol. 17. 1978. pp. 1375-1389.

5. MAP3S/RAINE Research Community. The MAP3S/RAINE Precipitation Chemistry Network: Statistical Overview for the Period 1976-1980. Pacific Northwest Laboratory, Richland, WA. 1980.

6. Physical Dynamics, Inc. Workshop on the Source-Receptor Relationship in Acid Precipitation: Implications for Generation of Electric Power from Coal. Held at La Jolla, Calif. on Jan. 18-20, 1982. Sponsored by U. S. Dept. of Energy. 1982.

7. Scott, B. C. "Sulfate Washout Ratios in Winter Storms." J. Appl. Meteor. 20. 1981. pp. 619-625.

8. Slinn, W. G. N. and J. M. Hales. Wet Removal of Atmospheric Particles. EPA Monograph, Washington, D.C. 1981.

9. Hales, J. M. "Precipitation Chemistry Investigations in the Continental United States." Sci. Total Environ. 16. 1980. pp. 1-11.

10. Levine, S. Z. and S. E. Schwarz. In-Cloud and Below-Cloud Scavenging of Nitric Acid Vapor. BNL-28683. U. S. DOE. Brookhaven National Laboratory, Upton, N.Y. 1980.

11. Sheih, C. M., et al. A Guide for Estimating Dry Deposition Velocities of Sulfur Over the Eastern United States and Surrounding Regions. ANL/RER-79-2. Argonne National Laboratory, Argonne, IL. 1979.

12. Hales, J. M. "Wet Removal Processes." Will Appear in EPA's Acid Rain Critical Assessment Document. U. S. EPA, Washington, D.C. 1981.

13. Hales, J. M. "OSCAR and Miscellany." MAP3S/RAINE Director's Memo. June 1, 1981. Pacific Northwest Laboratory, Richland, WA. 1981.

14. Scott, B. C. "Parameterization of Sulfate Removal by Precipitation." J. Appl. Meteor. 17. 1978. pp. 1375-1389.

15. Hales J. M. and M. T. Dana. "Regional-Scale Deposition of Sulfur Dioxide by Precipitation Scavenging." Atmos. Environ. 13. 1979. pp. 1121-1132.

16. Scott, B. C. and N. S. Laulainen. "On the Concentration of Sulfate in Precipitation." J. Appl. Meteor. 18. 1979. pp. 138-147.

17. Dana, M. T. "SO_2 Versus Sulfate Deposition in the Eastern United States." J. Geophys. Res. 85. 1980. pp. 4475-4480.

18. Shreffler, J. H. "A Model for the Transfer of Gaseous Pollutants to a Vegetational Surface." J. Appl. Meteor. 15. 1976. pp. 744-746.

19. Wesely, M. L. and B. B. Hicks. "Some Factors that Affect the Deposition Rates of Sulfur Dioxide and Similar Gases on Vegetation." APCA J. 27. 1977. pp. 1110-1116.

20. Crockett, A. B. and R. R. Kinnisor. "Mercury Residues in Soil Around a Large Coal-Fired Power Plant." Environ. Sci. & Tech. 13. 1979. pp. 712-715.

21. Aylor, D. E. "Deposition of Particles in a Plant Canopy." J. Appl. Meteor. 14. 1975. pp. 52-57.

22. Dana, M. T. and J. M. Hales. "Statistical Aspects of the Washout of Polydisperse Aerosols." Atmos. Environ. 10. 1976. pp. 45-50.

23. Hales, J. M. and M. T. Dana. "Precipitation Scavenging of Urban Pollutants by Convective Storm Systems." J. Appl. Meteor. 18. 1979. pp. 294-316.

24. Engelmann, R. J. and G. A. Sehmel. Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants (1974). Tech. Info. Center. ERDA. Washington, D.C. 1976.

25. Sehmel, G. A. "Particle Resuspension." Environ. International. 4. 1980. pp. 107-127.

26. Sehmel, G. A. "Particle and Gas Dry Deposition: A Review." Atmos. Environ. 14. 1980. pp. 983-1011.

27. Hales, J. M. MAP3S/RAINE Update. MAP3S 81-1. Battelle, Pacific Northwest Laboratories, Richland, WA. March 1981.

28. McMahon, T. A. and P. J. Denison. "Empirical Atmospheric Deposition Parameters-A Survey." Atmos. Environ. 13. 1979. pp. 571-585.

29. Moore, R. E. "Calculation of the Depletion of Airborne Pollutant Plumes Through Dry Deposition Processes." Environ. Int. 3. 1980. pp. 3-10.

30. Watson, C. W., et al. Rainout Assessment: The ACRA System and Summaries of Simulation Results. LA-6763. Los Alamos Scientific Laboratory, Los Alamos, NM. 1977.

31. Lewellen, W. S. and Y. P. Sheng. Modeling of Dry Deposition of SO_2 and Sulfate Aerosols. EA-1452. Electric Power Research Institute, Palo Alto, CA. 1980.

32. Yost, F. G. and E. A. Aronson. Markov Chain Model for Cloud Cover Sequences in Albuquerque. SAND-77-1430. Sandia Labs., Albuquerque, N.M. Oct. 1977.

33. Stedman, D. M. Final Report on Measurement of Surface Fluxes of Air Pollutants. DOE/EV/04958-T1. Michigan Univ., Ann Arbor, MI. 1981.

34. Raynor, G. S., J. V. Hayes and D. M. Lewis. Trajectory Analysis of Wet and Dry Deposited Pollens From Distant Sources. BNL-28980. Brookhaven National Lab., Upton, N.Y. 1981.

35. Lindberg, S. E., D. S. Shriner and W. A. Hoffman, Jr. Interaction of Wet and Dry Deposition with the Forest Canopy. CONF-810464-1. Oak Ridge National Lab., Oak Ridge, TN. 1981.

36. Hicks, B. B., M. L. Wesley and J. L. Durham. Critique of Methods to Measure Dry Deposition--Workshop Summary. EPA-600/9-80-050. EPA. Washington, D.C. 1980.

37. Scott, B. C. Predictions of In-Cloud Conversion Rates of SO_2 to SO_4 Based Upon a Simple Chemical and Kinematic Storm Model. PNL-S-8053-8. Pacific Northwest Laboratory, Richland, WA. 1981.

38. Hales, J. M. "Precipitation Chemistry: Its Behavior and Its Calculation." Air Pollutants and Their Effects on the Terrestrial Ecosystem. Edited by S. V. Krupa and A. H. Legge, John Wiley & Sons, Inc., New York, N.Y. 1981.

TABLE B-2f. VISIBILITY REFERENCES

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Visibility	1		X				X	X			X	X	Background Visibility (field)
	2	X	X			X	X	X		X	X	X	Plume and Regional Models
	3	X	X			X	X	X		X	X	X	Plume and Regional Models
	4	X	X			X	X	X		X	X	X	Plume and Regional Models
	5	X	X			X	X	X			X	X	Survey of Visibility Problems
	6	X				X	X			X	X		Plume Blight Modeling
	7	X				X	X			X	X		User's Manual for Plume Models
	8		X			X	X	X		X	X		Visibility in the Southwest
	9	X				X	X	X		X	X	X	Survey of Measurements and Theory
	10	X				X	X			X	X		L.A. Visibility versus Sulfate (field)
	11	X				X	X			X	X		Visibility Measurement Techniques
	12	X	X				X	X			X	X	Future Energy Impacts on Visibility
	13	X	X			X	X				X	X	Median versus Worst-Case Visibility
	14	X					X	X			X	X	Haze Due to Summer Aerosol Loading (research project)
	15	X					X	X			X	X	Haze Due to Summer Aerosol Loading (research project)
	16	X				X	X			X	X		Formation of Atmospheric Aerosol (research project)
	17	X				X	X			X	X		Formation of Atmospheric Aerosol (research project)
	18	X				X	X			X	X		Oxidants and Visibility (research project)
	19	X				X	X			X	X		Pregenitors of Atmospheric Visibility (research project)

(continued)

TABLE B-2f. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Visibility	20	X				X	X			X	X		Field Studies of Visibility Degradation (research project)
	21	X				X	X			X	X		Importance of Sulfates and Nitrates (research project)
	22		X			X	X	X		X	X	X	Visibility in the Southwest
	23		X			X	X	X		X	X	X	Visibility in the Southwest
	24		X			X	X	X		X	X	X	Visibility in the Southwest
	25		X			X	X			X	X	X	Visibility in Urban/Rural Areas
	26		X			X	X	X		X	X	X	Visibility in the Southwest
	27		X			X	X			X			Simulated-Photograph Technique to Study Visibility
	28		X			X	X	X			X	X	Visual Impacts of Western Development
	29		X			X	X				X	X	Background Visibility in Utah
	30	X				X	X			X	X		Intercomparison of Visibility Measurement Techniques
	31	X				X	X			X	X		Effects of Nonstandard Conditions
	32		X					X				X	Visibility in the Southwest
	33	X				X	X			X	X	X	Visibility Impairment and Energy
	34		X				X	X		X	X	X	Visibility and Dust in the West
	35		X					X			X	X	Factors Affecting Regional Visibility
	36			X		X	X			X	X	X	Visibility and Particle Monitoring Program
	37		X			X	X	X		X	X	X	Visibility in the Southwest
	END	-	-	-	-	-	-	-	-	-	-	-	---

REFERENCES

f. Visibility

1. Henderson, R. G., et al. Research Guidelines for Regional Modeling of Fine Particulates, Acid Deposition and Visibility. MTR-80W00148. The MITRE Corp., McLean, VA. 1980.

2. Latimer, D. A., et al. The Development of Mathematical Models for the Prediction of Anthropogenic Visibility Impairment (Volume I). EPA-450/3/78-110a. U. S. Environmental Protection Agency, Washington, D.C. 1978.

3. Latimer, D. A., et al. The Development of Mathematical Models for the Prediction of Anthropogenic Visibility Impairment: Volume II, Appendices. EPA-450/3/78-110b. U. S. Environmental Protection Agency, Washington, D.C. 1978.

4. Latimer, D. A. The Development of Mathematical Models for the Prediction of Anthropogenic Visibility Impairment: Volume III, Case Studies for Selected Scenarios. EPA-450/3/78-110c. U. S. Environmental Protection Agency, Washington, D.C. 1978.

5. U. S. EPA. Protecting Visibility: An EPA Report to Congress. EPA-450/5-79-008. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1979.

6. Latimer, D. A. and R. G. Ireson. Workbook for Estimating Visibility Impairment. EPA-450/4-80-031. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1980.

7. Johnson, C. D., et al. User's Manual for the Plume Visibility Model (PLUVUE). EPA-450/4-80-032. U. S. Environmental Protection Agency, Research Triangle Park, N.C. 1980.

8. Trijonis, J. Visibility in the Southwest-An Exploration of the Historical Data Base. Paper No. 78-43.7. Pres. at the 71st Annual Meeting of the Air Pollution Control Assoc. Held at Houston, Texas. 25-30 June 1978.

9. Malm, W. "Considerations in the Measurement of Visibility." APCA. 29. 1979. pp. 1042-1052.

10. Cass, G. R. "On the Relationship Between Sulfate Air Quality and Visibility with Examples in Los Angeles." Atmos. Environ. 13. 1979. pp. 1069-1084.

11. Tombach, I. A Critical Review of Methods for Defining Visual Range in Pristine and Near-Pristine Areas. Paper No. 78-43.2. Pres. at the 71st Annual Meeting of the Air Pollution Control Assoc. Held at Houston, Texas. 25-30 June 1978.

12. Nochumson, D., et al. National Impacts on Visual Air Quality from a Future Energy Scenario. LA-UR-79-3214. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1979.

13. Gins, J. D., et al. Statistical Relationships Between Median Visibility and Conditions of Worst-Case Manmade Impact on Visibility. LA-UR-80-2485. Los Alamos Scientific Lab., Los Alamos, N.M. 1980.

14. Wesely, M. L. Regional Haze Effects on Climate. SSIE No. FJ-2268. U. S. Dept. of Energy, Germantown, MD. 1981.

15. Hicks, B. B. Climate: Regional-Scale Haze Transport and Effects. SSIE No. FQ-1236. U. S. Dept. of Energy, Germantown, MD. 1981.

16. Whitby, K. T. Formation of Atmospheric Aerosols. SSIE No. GMA-2528-4. U. S. EPA, Research Triangle Park, N.C. 1981.

17. Whitby, K. T. Formation of Atmospheric Aerosol. SSIE No. GMA-3942-2. U. S. EPA, Research Triangle Park, N.C. 1981.

18. Reiss, N. M. Relationships Between Certain Air Pollutants and Various Meteorological Factors. SSIE No. GY-5009-11. U. S. Dept. of Agriculture, New Brunswick, N.J. 1981.

19. Twomey, S. Atmospheric Visibility. SSIE No. GQN-575114-2. U. S. Dept. of Defense, Arlington, VA. 1981.

20. Waggoner, A. P. and R. J. Charlson. Optical Effects of Atmospheric Aerosol. SSIE No. GMA-6124. U. S. EPA, Research Triangle Park, N.C. 1981.

21. Tang, I. N., et al. The Relative Importance of Atmospheric Sulfates and Nitrates in Visibility Reduction. BNL-28346. U. S. DOE, Brookhaven National Laboratory, Upton, N.Y. 1980.

22. Malm, W., et al. Visibility in the Southwest. Environmental Monitoring Systems Laboratory. U. S. EPA, Las Vegas, NV. 1979.

23. Marians, M. and J. Trijonis. Empirical Studies of the Relationship Between Emissions and Visibility in the Southwest. Technical Service Corp., Santa Fe, N.M. 1979.

24. Trijonis, J. Visibility in the Southwest: An Exploration of the Historical Data Base. Atmos. Environ. 13. 1979. pp. 833-834.

25. Trijonis, J. and D. Shapland. Existing Visibility Levels in the U.S.: Isopleth Maps of Visibility in Suburban/Nonurban Areas During 1974-1976. EPA-450/5-79-010. U. S. EPA, Research Triangle Park, N.C. 1979.

26. Trijonis, J. and K. Yuan. Visibility in the Southwest: An Exploration of the Historical Data Base. EPA-600/3-78-039. U. S. EPA, Washington, D.C. 1978.

27. Williams, M. D., *et al*. The Simulated-Photograph Technique as a Tool for the Study of Visibility Impairment. LA-8105-MS. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1979.

28. Nochumson, D., *et al*. Potential Future Impacts on Visual Air Quality for Class I Areas. LA-UR-79-1141. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1979.

29. Allee, P. A. and R. F. Pueschel. A Study of Visibility in Carbon and Emery Counties, Utah. NOAA-DR-ERL-ARL-1, NOAA-80082606. NOAA, Air Resources Lab., Silver Spring, MD. 1980.

30. Tombach, I. and D. Allard. "Intercomparison of Visibility Measurement Methods." J. APCA. 30. 1980. pp. 134-142.

31. Allard, D. and I. Tombach. "The Effects of Non-Standard Conditions on Visibility Measurements." Atmos. Environ. 15. 1981. pp. 1847-1857.

32. Malm, W. C., *et al*. "Visibility in the Southwestern United States from Summer 1978 to Spring 1979." Atmos. Environ. 15. 1981. pp. 2031-2042.

33. Males, R. "R & D Status Report of Energy Analysis and Environmental Division: Visibility Impairment." EPRI Journal. 11. 1980. pp. 49-50.

34. Hall, F. F., Jr. "Visibility Reductions From Soil Dust in the Western U.S." Atmos. Environ. 15. 1981. pp. 1929-1933.

35. Pitchford, A., *et al*. "Regional Analysis of Factors Affecting Visual Air Quality." Atmos. Environ. 15. 1981. pp. 2043-2054.

36. Pitchford, A., *et al*. Determining Oil Shale Impact: A Visibility and Particle Monitoring Program. Draft Report. Environmental Monitoring Systems Laboratory. U. S. EPA, Las Vegas, NV. 1981.

37. Trijonis, J. "Visibility in the Southwest-An Exploration of the Historical Data Bases." Atmos. Environ. 13. 1979. pp. 833-843.

TABLE B-2g. REFERENCES ON THE EFFECTS (AIR QUALITY RELATED VALUES) OF POLLUTANTS ON SOIL, WATER, FLORA AND FAUNA

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Effects (Air Quality Related Values)	1	X				X	X				X	X	Coal, Fish and Wildlife (lab)
	2	X					X	X				X	U.S. Acid Rain Plan (field, theory)
	3	X				X	X				X	X	Coal, Wildlife, Field, Lab
	4	X			X	X					X	X	Acid Rain Effects on Plants
	5	X						X			X	X	Global Monitoring of Turbidity and Acid Rain
	6	X		X	X	X					X	X	Effects of Syn. Fuels on Ecology
	7	X					X	X				X	Effects of Acid Rain in North America
	8	X				X	X				X	X	PAH Levels in Soils, Plants, Water (research project)
	9	X				X	X				X	X	Biological Monitoring Methods (research project)
	10	X			X	X					X	X	Impacts of Low pH on Fish
	11	X				X	X					X	Forest Canopies and Acid Rain
	12		X			X	X	X			X	X	Acid Rain in Western U.S.
	13	X			X	X	X			X	X	X	Ecological Effects of Using Ammonia
	14	X				X	X	X			X	X	Impacts of Acid Rain on Ecosystems
	15	X				X	X	X			X	X	Impacts of Coal Conversion
	16		X		X	X					X	X	Trace Elements From a Power Plant
	17		X		X	X					X	X	Trace Elements From a Power Plant
	18			X	X	X	X				X	X	Oil Shale Industry Impacts on Flat Top Wilderness Area
	19	X			X	X	X				X	X	Burdening Capacity of Ecosystems

(continued)

TABLE B-2g. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Effects (Air Quality Related Values)	20	X			X	X	X				X	X	Ecological Effects of Energy-Related Pollutants
	21	X			X	X				X	X	X	Effects of Acid Rain on Plant Pathogens
	22	X			X	X	X				X	X	Air Pollution Effects on Plants
	23	X			X	X					X	X	Vegetative Changes Near Sources
	24	X			X	X	X					X	Pollution Effects on Predator-Prey Interactions
	25	X			X	X	X	X			X	X	SO_2 and NO_x Effects on Vegetation
	26			X	X	X	X				X	X	Ecological Effects of Oil Shale Development
	27			X	X	X	X				X	X	Ecological Effects of Oil Shale Development
	28			X	X	X						X	Revegetation in the Piceance Basin
	END	-	-	-	-	-	-	-	-	-	-	-	----

REFERENCES

g. Effects

1. Dvorak, A. J., *et al.* Impacts of Coal-Fired Power Plants on Fish, Wildlife, and their Habitats. FWS/OBS-78/29. U. S. Fish and Wildlife Service, Ann Arbor, MI. 1978.

2. Interagency Task Force on Acid Precipitation. National Acid Precipitation Assessment Plan. Draft Report. Council on Environmental Quality, Washington, D.C. 1981.

3. Newman, J. R. Effects of Air Emissions on Wildlife Resources. FWS/OBS-80/40.1. Fish and Wildlife Service. U. S. Dept. of Interior, Washington, D.C. 1980.

4. Pagel, J. E. A Review of Microbiological Processes Relevant to the Effects of Acidic Precipitation. Micro 8101. Ontario Ministry of the Environment, Toronto, Ontario. 1981.

5. National Climatic Center. Global Monitoring of the Environment for Selected Atmospheric Constituents - 1975. NOAA-81012910. National Oceanic and Atmospheric Administration. National Climatic Center, Asheville, N.C. 1977.

6. Rickert, L. W. and J. L. Seiber. Publications in Life Sciences Synthetic Fuels of Oak Ridge National Laboratory. ORNL/TM-7680. Oak Ridge National Laboratory, Oak Ridge, TN. 1981.

7. Glass, N. R., *et al.* Effects of Acid Precipitation. EPA-600/J-79-113. See Environ. Sci. and Tech. Vol. 13. 1979. pp. 1350-1355.

8. Harkin, J. M. Polycyclic Aromatic Hydrocarbons in the Atmosphere. SSIE No. GY-65717-3. U. S. Dept. of Agriculture. Coop. Res. Office, Madison, Wisconsin. 1981.

9. Rogers, R. D., *et al.* Develop and Apply Biological Monitoring Methods. SSIE No. ZMA-1081-2. U. S. EPA, Las Vegas, NV. 1981.

10. Fritz, E. S. Potential Impacts of Low PH on Fish and Fish Populations. FWS/OBS-80/40.2. U. S. Dept. of Interior, Ann Arbor, MI. 1980.

11. Hoffman, W. A., *et al.* "Precipitation Acidity: The Role of the Forest Canopy in Acid Exchange." J. Environ. Qual. 9. 1980 pp. 95-100.

12. Lewis, W. M., Jr. and M. C. Grant. "Acid Precipitation in the Western United States." Science. 207. 1980. pp. 176-177.

13. Orgill, M. M. and D. J. McNaughton. Trace Ecological Effects of Increased Ammonia Usage. PNL-3384. Pacific Northwest Laboratory, Richland, WA. 1980.

14. Shriner, D. S., *et al*. Atmospheric Sulfur Deposition - Environmental Impact and Health Effects. Ann Arbor Science Publ. Inc., Woburn, MA. 1980.

15. Braunstein, H. M., *et al*. Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview. Ann Arbor Science Publ., Inc. Woburn, MA. 1981.

16. Schock, M. R., *et al*. The Long-Term Effects of Trace Elements Emitted by Energy Conversion of Lignite Coal. Vol. 1. N. Dakota State Dept. of Health, Bismarck, N.D. 1979.

17. Morrison, W. W., *et al*. The Long-Term Effects of Trace Elements Emitted by Energy Conversion of Lignite Coal. Volume II. Tech. App. N. Dakota Dept. of Health, Bismarck, N.D. 1979.

18. Murphy, D. J., D. G. Fox and D. Haddow. Air Quality, Oil Shale, and Wilderness...A Workshop to Help Identify and Protect Air Quality Related Values of the Flat Tops. U. S. Dept. of Agriculture Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO. 1981.

19. Mueller, P. Burdening Capacity of Ecosystems. AED-Conf.77-002-010. Universität des Saarlandes, Saarbrücken (Germany, F.R.). 1977.

20. Platt, R.B., H. L. Ragsdale, W. H. Murdy and D. J. Shure. Ecological Behavior and Effects of Energy Related Pollutants. ORO-2412-85. Dept. of Biology. Emory Univ., Atlanta, GA. 25 Oct. 1977.

21. Shriner, D. S. and E. B. Cowling. Effects of Rainfall Acidification on Plant Pathogens. CONF-780573-1. Oak Ridge National Lab., Oak Ridge, Tenn. 1978.

22. Studies of Air Pollution Effects on Vegetation. UCID-17714. California Univ., Livermore, CA. Lawrence Livermore Lab., Jan. 1978.

23. Davis, D. D. and S. P. Pennypacker. Likelihood Estimations of Vegetative Alternation Near Known or Proposed Sources of Air Pollution. 1st Annual Progress Report. COO-4497-1. Pennsylvania State Univ., University Park, PA. Aug. 1978.

24. Coutant, C.C., R. E. McLean and D. L. DeAngelis. Influences of Physical and Chemical Alternations on Predator-Prey Interactions. CONF-780785-1. Oak Ridge National Lab., Oak Ridge, TN. 1978.

25. Weinstein, L. H., D. C. McCune and D. C. MacLean. Effects of Sulfur Dioxide and Nitrogen Dioxide on Vegetation. Progress Report. 1 June - 30 December 1978. COO-4368-2. Boyce Thompson Inst. for Plant Research, Ithaca, N.Y. Jan. 1979.

26. Ecological Effects of Oil Shale Development: Problems, Perspectives, and Approaches. LA-UR-80-2860. Los Alamos Scientific Lab., N.M. 1980.

27. Chappell, W. R. Oil Shale Research and Coordination. Progress Report. 1980-1981. DOE/EV/10298-T1. Denver Univ., Denver,CO. 1981.

28. Revegetation Research on Oil Shale Lands in the Piceance Basin. COO-4018-5. Dept. of Range Science. Colorado State Univ., Fort Collins, CO. Feb. 1981.

TABLE B-2h. REFERENCES ON INSTRUMENTS AND INSTRUMENT SYSTEMS

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Instrument Systems	1	X				X	X		X	X			PBL Instruments, Wind, Turbulence
	2	X			X	X			X	X	X		LIDAR, Wind, Turbulence
	3	X			X	X			X	X			LIDAR and Fluorescent Tracers Wind, Turbulence
	4	X			X	X	X		X	X	X		Wind Tunnels to Mesonetworks Wind and Turbulence
	5	X						X		X	X		Synoptic Windfinding Techniques
	6	X	X			X	X	X		X	X		Multitracer Atmospheric Exp.
	7	X			X	X			X	X	X		DIAL, Methane Detection
	8	X			X	X	X		X	X	X		OPRA-Computer Analysis Program (radiation)
	9	X					X	X	X	X	X		Infrared Backscatter Spectra
	10	X				X	X		X	X	X		Remote Analysis of Aerosols by LIDAR
	11	X				X	X		X	X	X		Remote Analysis of Aerosols by LIDAR
	12	X			X	X			X	X	X		Remote Analysis of Gases by Lasers
	13	X					X	X		X	X	X	Multipurpose Scanning Photometer
	14	X			X	X	X		X	X	X		Lasers and Acoustic Dopplers
	15	X			X	X	X		X	X	X		LIDAR Remote Sensing
	16	X					X	X		X			Long-Range Tracer Study
	17	X			X	X			X	X			Laser Systems
	18	X			X	X			X	X			LIDAR and Fluorescent Dye
	19	X				X	X	X		X	X	X	Satellite Energy and Moisture Budgets of the Earth
	20	X			X	X			X	X			Airborne LIDAR

(continued)

TABLE B-2h. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Instrument Systems	21	X			X	X	X		X	X	X		Conference on Meteor. Measurement Systems
	22	X			X	X			X	X	X		Remotely Sensed SO_2 in Plumes
	23	X			X	X			X	X			Sampling and Analytic Techniques for Pollutants From Vehicles (research project)
	24	X			X	X			X	X	X		Optimal Monitoring Network (research project)
	25	X			X	X			X	X	X		Optimal Monitoring Network (research project)
	26	X			X	X			X	X	X		Oxidant Monitoring Network Design (research project)
	27	X			X	X	X		X	X	X		Airborne LIDAR System (research project)
	28	X			X	X	X		X	X			Acoustic Sounder Theory
	29	X			X	X			X	X			Thermal Plumes Detected via Acoustic Sounders
	30	X			X	X	X		X	X			Papers on Acoustic Sounders
	31	X			X				X	X			Individual Air Pollution Monitors
	32	X			X	X			X	X			Tethersonde Systems for Wind and Temperature
	33	X			X	X	X		X	X			Analysis Techniques for Gases and Particles
	34	X			X	X			X	X			Use of an Infrared Transmissometer
	35	X			X	X			X	X			Sodar and Laser Scintillation
	36	X				X				X	X		Network Design of PSD Requirements
	37	X			X	X			X	X	X		Site Selection of Monitoring Networks

(continued)

TABLE B-2h. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Instrument Systems	38	X			X	X			X	X	X		Site Selection for Photochemical Measurements
	39	X			X	X			X	X	X		Advances in Particle Sampling
	40	X			X	X	X		X	X	X	X	Symp. on Remote Sampling
	41	X			X	X	X		X	X	X	X	Symp. on Remote Sampling
	42	X			X	X	X		X	X	X	X	ASTM Standards on Sampling
	43	X			X				X	X	X		Onsite Meteorological Instrumentation
	END	–	–	–	–	–	–	–	–	–	–	–	----

TYPING GUIDE SHEET

REFERENCES

h. Instrument Systems

1. Lenshow, D. H. (Editor). Atmospheric Technology: Instruments and Techniques for Probing the Atmospheric Boundary Layer. No. 7. National Center for Atmospheric Research, Boulder, CO. 1975.

2. Uthe, E. E. and W. B. Johnson. Application of Lidar Techniques to Estimating Atmospheric Dispersion. NUREG/CR-1835. U. S. Nuclear Regulatory Commission, Washington, D.C. 1980.

3. Konrad, T. G. and J. R. Rowland. A New Technique for Measuring Fine Scale Wind Profiles Using Lidar and a Fluorescent Tracer. SIR800-001. Appl. Physics Lab. The Johns Hopkins Univ., Laurel, MD. 1980.

4. Cox, R. (Editor). Atmospheric Technology. No. 6. National Center for Atmospheric Research, Boulder, CO. 1974-75.

5. Lally, V. E. (Editor). Atmospheric Technology. No. 10. National Center for Atmospheric Research, Boulder, CO. 1978-1979.

6. Clements, W. E. (Editor). Experimental Design and Data of the April 1977 Multitracer Atmospheric Experiment at the Idaho National Engineering Laboratory. LA-7795-MS. Los Alamos National Laboratory, Los Alamos, N.M. 1979.

7. Murray, E. R. and R. S. Vickers. Remote Detection of Methane Using a Differential-Absorption Lidar. Stanford Research Institute, Menlo Park, CA. 1976.

8. Wright, M. L. OPRA: A Computer Code for Optical Propagation and Radiation Analysis. Stanford Research Institute, Menlo Park, CA. 1977.

9. Colburn, D. S. and J. B. Pollack. "Infrared Backscatter Spectra for Differentiation of Stratospheric Aerosol Composition." Presented at the Seventh International Laser Radar Conference. Stanford Research Institute, Menlo Park, CA. November 4-7, 1975.

10. Wright, M. L., J. B. Pollack and D. S. Colburn. "DISC--A Technique for Remote Analysis of Aerosols by Differential Scatter. Presented at the Seventh International Laser Radar Conference. Stanford Research Institute, Menlo Park, CA. November 4-7, 1975.

11. Wright, M. L., J. B. Pollack and D. S. Colburn. "Remote Analysis of Aerosols by Differential Scatter (DISC) Lidar Systems. Presented at the Eighth Materials Research Symposium. National Bureau of Standards, Gaithersburg, Maryland, September 20-24, 1976.

12. Murray, E. R. "Remote Measurements of Gases Using Discretely Tunable Infrared Lasers." Proc. of the Soc. of Photo-Optical Instrumentation Engineers. Vol. 95. 1976. pp. 96-104.

13. Kleckner, E. W., _et al_. A Multipurpose Computer-Controlled Scanning Photometer. Pacific Northwest Laboratory, Richland, WA. 1981.

14. Cliff, W. C. Laser and Acoustic Doppler Techniques for the Measurement of Fluid Velocities. NASA TMX-64932. NASA. Geo. C. Marshall Space Flight Center. Marshall Space Flight Center, Alabama. 1975.

15. C. G. Corp. Computer Genetics Corporation Lidar Remote Sensing Experience and Product/Service Capability. Computer Genetics Corp., Wakefield, MA. 1981.

16. Ferber, G. J., _et al_. Demonstration of a Long-Range Atmospheric Tracer System Using Perfluorocarbons. NOAA Tech. Memo. ERL ARL-101. Air Resources Laboratories, Silver Spring, Maryland. 1981.

17. Byer, R. L. and E. R. Murray. "Remote Monitoring with Laser Sources." Air Pollution Analysis. Chapman & Hall Ltd. London, England, 1977. pp. 406-449.

18. Rowland, J. R. and T. G. Konrad. A New Technique for the Study of Power Plant Plume Behavior Using Fluorescent Dye as Tracers and Lidar as the Remote Sensor. Rep. No. SIR79U-003. Applied Physics Laboratory. The John Hopkins University, Laurel, MD. 1979.

19. Carlson, T. N., _et al_. "Satellite Estimation of the Surface Energy Balance, Moisture Availability and Thermal Inertia." J. of Appl. Meteor. Vol. 20. 1981. pp. 67-87.

20. Uthe, E. E., _et al_. Development of an Airborne Lidar for Characterizing Particle Distribution in the Atmosphere. Final Report. EPRI-EA-1538. Electric Power Research Institute, Palo Alto, CA. 1980.

21. Hines, J. and G. Bingham. Meteorological Measurement System for Support of Atmospheric Propagation Studies. CONF-8003101-1. Army Electronics Research and Development Command. Atm. Sci. Lab., White Sands Missile Range, N.M. 1980.

22. Sperling, R. B., _et al_. Accuracy of Remotely Sensed SO_2 Mass Emission Rates. EPA/600/2-79/094. U. S. EPA, Research Triangle Park, N.C. 1979.

23. Bradow, R. L., *et al*. Sampling and Analysis Techniques for Pollutants from Mobile Sources. SSIE No. ZMA-980-2. U. S. EPA, Research Triangle Park, N.C. 1981.

24. Liu, M. Optimal Number of Air Monitoring Sites. SSIE No. GMA-5004-1. U. S. EPA, Research Triangle Park, N.C. 1981.

25. Behar, J. B., *et al*. Optimum Air Quality Monitoring Network Design Methodology. SSIE No. ZMA-1075-Z. U. S. EPA, Las Vegas, NV. 1981.

26. Behar, J. B., *et al*. Oxidant Monitoring Network Design in Tampa/St. Petersburg. SSIE No. ZMA-1515-1. U. S. EPA, Las Vegas, NV. 1981.

27. Eckert, J. A. Develop Airborne Lidar System for Monitoring Atmospheric Particulates. SSIE No. ZMA-1077-3. U. S. EPA, Las Vegas, NV. 1981.

28. Phillips, P. D., *et al*. "Layer Model for Assessing Acoustic Refraction Effects in Echo Sounding." J. Acoust. Soc. Am. 62. 1977. pp. 47-55.

29. Nater, W. and H. Richner. "Thermal Plumes Detected by an Acoustic Echo Sounder." J. Appl. Meteor. 16. 1977. pp. 67-70.

30. Richner, H., *et al*. Collected Papers on Acoustic Echo Sounding, Gravity Waves and Biometeorology. Lapeth-13. Laboratorium Für Atmosphären-physik, Zürich, Switzerland. 1977.

31. Morgan, M. G. and S. C. Morris. "Needed: A National R & D Effort to Develop Individual Air Pollution Monitor Instrumentation." APCA J. 27. 1977. pp. 670-673.

32. Tapp, R. G. and R. C. Lile. "A New Tethersonde System for Remote Measurement of Wind and Temperature." Boundary-Layer Meteorology. 15. 1978. pp. 465-479.

33. Katz, M. "Advances in the Analysis of Air Contaminants: A Critical Review." APCA J. 30. 1980. pp. 528-557.

34. Uthe, E. E. "Evaluation of an Infrared Transmissometer for Monitoring Particulate Mass Concentrations of Emissions from Stationary Sources." APCA J. 30. 1980. pp. 382-386.

35. Coulter, R. L. and M. L. Wesley. "Estimates of Surface Heat Flux from Sodar and Laser Scintillation Measurements in the Unstable Boundary Layer." J. of Appl. Meteor. 19. 1980. pp. 1209-1222.

36. Raufer, R. K., et al. "Air Monitoring Network Design to Meet PSD Requirements." Power Engineering. February 1979. pp. 63-65.

37. Noll, K. E., *et al.* "An Objective Air Monitoring Site Selection Methodology for Large Point Sources." Atmos. Environ. 11. 1977. pp. 1051-1059.

38. Ludwig, F. L. and E. Shelar. Site Selection for the Monitoring of Photochemical Air Pollutants. EPA-450/3-78-013. U. S. EPA, Research Triangle Park, N.C. 1978.

39. Liu, B. Y. H., *et al.* "Advances in Particle Sampling and Measurement." Environ. Sci. and Tech. 14. 1980. pp. 392-397.

40. Proceedings of the Eleventh International Symposium on Remote Sensing of Environment. Volume I. CONF-770478-P1. Center for Remote Sensing Information and Analysis. Environmental Research Inst. of Michigan. Ann Arbor, MI. 1977.

41. Proceedings of the Eleventh International Symposium on Remote Sensing of Environment. Volume II. CONF-770478-P2. Center for Remote Sensing Information and Analysis. Environmental Research Inst. of Michigan. Ann Arbor, MI. 1977.

42. ASTM. Sampling and Analysis of the Atmosphere. Annual Book of ASTM Standards. Part 26. American Society for Testing and Materials, Philadelphia, PA. 1981.

43. Hoffnagle, G. F., M. E. Smith, T. V. Crawford and T. J. Lockhart. "On-site meteorological instrumentation requirements to characterize diffusion from point sources--a workshop." Bull. Am. Meteorol. Soc. 62. 1981. pp. 255-261.

TABLE B-2i. DATA MANIPULATION REFERENCES

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Data Manipulation	1	X				X			X	X			ASCOT System, Wind, Turbulence
	2	X			X	X	X	X	X	X	X	X	Easy Access to Data Bases
	3	X			X	X	X	X	X	X	X	X	Management of Diverse Environmental Data with SAS
	4	X			X	X	X					X	Geographic Data Base
	5	X			X	X	X	X	X	X	X	X	Interactive Information Retrieval Programs
	6	X			X	X	X			X	X	X	Stochastic Analysis of Air Pollution Data
	7	X			X	X	X	X	X	X	X	X	Portable Graphics Package
	8	X			X	X	X	X	X	X	X	X	Computer Mapping Software
	9	X			X	X	X	X	X	X	X	X	Computer Graphics Software
	10	X			X	X	X		X	X	X		Data Acquisition and Analysis System
	END	-	-	-	-	-	-	-	-	-	-	-	----

REFERENCES

i. Data Manipulation

1. Barbieri, J., et al. The ASCOT Data Base Management System. UCID-18752 & ASCOT/80/6. Lawrence Livermore Laboratory, Livermore, CA. 1980.

2. Karlgaard, R. "DATATRAN for Easy Access." EPRI J. 6. 1981. pp. 14-17.

3. Olson, R. J. and R. H. Strand. Management of Diverse Environmental Data With SAS. CONF-780147-1. Oak Ridge National Lab., Oak Ridge, TN. 1977.

4. Hones, B. and P. Johnson. Computer Mapping Software and Geographic Data Base Ment: Oak Ridge National Laboratory User Experience. CONF-780727-1. Oak Ridge National Lab., Oak Ridge TN. 26 July.1978.

5. Haeuslein, G. K. On The Design of an Interactive Information Retrieval Program. CONF-780990-1. Oak Ridge National Lab., Oak Ridge, TN. 1979.

6. Chernick, M. R. Limit Theorem for the Maximum of Autoregressive Processes with Uniform Marginal Distributions and its Implications to the Analysis of Air Pollution Data. COO-2874-37. Stanford Univ., Stanford, CA. July 1978.

7. George, J. E. Portable Graphics. LA-UR-77-1931. Los Alamos Scientific Lab., Los Alamos, N.M. 1977.

8. Wood, P. M. and W. H. Benson. Computer Mapping Software at the Lawrence Berkeley Laboratory. LBL-7938. Lawrence Berkeley Lab. California Univ., Berkeley, CA. June 1978.

9. Clifford, T. S. Introduction to Graphics at the CSCP. BNL-50788. Brookhaven National Lab., Upton, N.Y. April 1978.

10. Logg, C. A. and R. L. A. Cottrell. Atropos: A Versatile Data Acquisition and Analysis System. SLAC-PUB-2220. Stanford Univ., Stanford, CA. 1978.

TABLE B-2j. REFERENCES ON OIL SHALE PROCESSES AND RESOURCES

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Oil Shale Processes and Resources	1			X		X	X					X	Oil Shale Resource, Communities
	2			X		X	X					X	Oil Shale Resource, Piceance Creek
	3			X	X	X						X	Oil Shale Resources and Processes in Utah and Colorado
	4			X	X	X						X	Oil Shale Resource and Process Status
	5			X	X							X	Fluid-Bed Retorting
	6			X	X							X	Surface Retorting
	7			X	X							X	In-Situ Retorting
	8			X	X	X	X					X	Yampa and White Basin Development
	9			X	X	X	X					X	Retorting of Colorado's Oil Shale
	10			X	X	X						X	In-Situ Microwave Processing
	11			X	X	X						X	True In-Situ Process (Utah)
	12			X	X	X						X	Math Model: MIS Process
	13			X		X	X					X	Green River Resource (modeling)
	14			X	X	X	X					X	Piceance Creek Basin
	15			X	X	X						X	Modeling of MIS Processes
	16			X	X	X						X	Oil Shale Retorting
	17			X	X	X						X	MIS Retorting
	18			X	X	X	X					X	Synfuel Energy Resources
	19		X	X	X	X	X					X	Commercial Oil Shale Projects
	20		X		X	X						X	Rf Heating of Utah Tar Sands
	21			X	X	X						X	Vertical MIS Retort
	22			X	X	X						X	Oil Shale Development for DOD
	23	X		X	X	X	X					X	Synfuel Development for DOD
	24			X	X	X						X	Solar Oil Shale Retorting

(continued)

TABLE B-2j. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Oil Shale Processes and Resources	25			X	X	X						X	Oil Shale Retorting
	26	X		X	X	X	X					X	Synthetic Fuel Industry
	27			X	X	X						X	MIS Retorting and Above-Ground Retorting
	28			X	X	X						X	Surface Oil Shale Retorting
	29			X	X					X	X		Modeling of a Retort Run
	30			X	X				X	X	X	X	Storage Stability of Shale Oil Fuels
	31			X	X							X	Characteristics of Oil Shale Fuels
	32			X	X							X	Synthetic Fuels From Oil Shale
	33			X	X	X			X	X			Modeling of MIS Retorting
	34			X	X	X						X	Description of Oil Shale Processes
	35			X	X	X						X	MIS Retorting Report
	36			X	X	X						X	Occidental In-Situ Process
	37			X	X	X	X					X	Oil Shale Resources in Colorado, Utah and Wyoming
	38			X	X	X						X	Bx In-Situ Oil Shale Project
	39			X	X	X						X	Bx In-Situ Oil Shale Project
	40			X	X	X	X			X	X	X	API's Assessment of Oil Shale Industry
	41			X	X	X						X	Surface Retorting
	42			X	X	X						X	Paraho Process Characterization
	43			X	X	X						X	Hytort Process: Technical and Economic
	44			X	X	X						X	Occidental Vertical MIS Process
	45			X	X	X						X	Geokinetics Horizontal In-Situ Process

(continued)

TABLE B-2j. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Oil Shale Processes and Resources	46			X	X							X	HTGR-PS/G Plant Appl. Study
	47			X	X	X					X	X	Lawrence-Livermore Oil Shale Project
	48			X	X	X					X	X	Lawrence-Livermore Oil Shale Project
	49			X	X						X	X	In-Situ Oil Shale Recovery
	50			X	X						X	X	Oil Shale Extraction Processes
	END	-	-	-	-	-	-	-	-	-	-	-	----

j. Oil Shale Processes & Resources

1. Colorado, Dept. of Natural Resources. Colorado Oil Shale: The Current Status. Colorado Geological Survey, Denver, CO. 1979.

2. Carpenter, R. H., *et al*. Oil Shale Resource Assessment for In-Situ Retorting, Phase 1: Piceance Creek Basin, Colorado. UCRL-52687. Lawrence Livermore Laboratory, Livermore, CA. 1979.

3. Hessel, D. and G. Strasser. Western Oil Shale Development: A Technology Assessment (Volume 1: Main Report). PNL-3830. Vol. 1. Pacific Northwest Laboratory, Richland, WA. 1981.

4. Jacobs Eng. Group, Inc. Environmental Perspective on the Emerging Oil Shale Industry. Volume 2 and Appendices. EPA-600/2-80-205B. U. S. EPA, Research Triangle Park, N.C. 1981.

5. Barnes, J. W. Hydrogen Production by Fluid-Bed Retorting of Oil Shale. Rep. No. LA-8832-MS. Los Alamos National Laboratory, Los Alamos, N.M. 1981.

6. Aerospace Corp. Oil Shale Surface Retorting: Environmental Characterization Information Report. DOE/EP-0015. U. S. DOE, Germantown, MD. 1981.

7. U. S. DOE. Environmental Assessment: Geolsinetics, Inc. Oil Shale Research Project, Uintah County, Utah. DOE/LETC/EA-0114. U. S. Dept. of Energy, Washington, D.C. 1979.

8. Melancon, S. M., *et al*. Assessment of Energy Resource Development Impact on Water Quality: The Yampa and White River Basin. EPA-600/7-80-151. U. S. Environ. Protection Agency, Las Vegas, NV. 1980.

9. Hemming, D. F. Energy Requirements for the Production of Synthetic Crude Oil from Colorado Oil Shales. ERG-012. Open Univ., Milton Keynes. Energy Research Group. England. 1976.

10. Wall, E. T. In Situ Noncombustive Microwave Processing of Oil Shale. Final Report. Colorado Univ. at Denver. Dept. of Electrical and Computer Engineering. Denver, CO. 1979.

11. Hutchinson, D. L. Investigation of the Geokinetics Horizontal In-Situ Oil-Shale-Retorting Process. 4th Annual Report, 1980. DOE/LC/10787-73. U. S. DOE, Washington, D.C. 1981.

12. Braun, R. L. Mathematical Modeling of Modified In-Situ and Aboveground Oil Shale Retorting. UCRL-53119. Lawrence Livermore Laboratory, Livermore, CA. 1981.

13. Davis, F. G. F., Jr. and J. W. Smith. Case Study of an Application of Computer Mapping in Oil-Shale Resource Mapping. CONF-7907-39-2. U. S. DOE. Laramie Energy Tech. Center, Laramie, WY. 1979.

14. Carpenter, R. H., *et al*. Oil Shale Resource Assessment for In-Situ Retorting, Phase 1: Piceance Creek Basin, Colorado. UCRL-52687. Lawrence Livermore National Laboratory, Livermore, CA. 1979.

15. Rothman, A. J. Lawrence Livermore National Laboratory Oil Shale Project. Quarterly Report October - December 1980. UCID-16986-80-4. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

16. Rothman, A. J. Lawrence Livermore National Laboratory Oil Shale Project. Quarterly Report, July-September 1980. UCID-16986-80-3. Lawrence Livermore National Laboratory, Livermore, CA. 1980.

17. Slawson, G. C., Jr. Monitoring Groundwater Quality: The Impact of In-Situ Oil Shale Retorting. EPA-600/7-80-132. U. S. EPA, Research Triangle Park, N.C. 1980.

18. Grace, S. R. and T. L. Thoem. Synthetic Fuels Projects Status Report. Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming. EPA-908/4-80-001. U. S. EPA, Denver, CO. 1980.

19. Conference (1982). Energy Technology Conference and Exposition held 16-18 February 1982 at Washington, D.C. 1982.

20. Bridges, J., *et al*. Rf Heating of Utah Tar Sands. Final Report. October 1978-December 1979. DOE/CH/90035-4. U. S. Dept. of Energy, Washington, D.C. 1980.

21. Campbell, J. H., *et al*. Analysis of the Operation of Occidental's Modified In-Situ Retort 6. UCRL-85312. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

22. Davis, R. M., *et al*. The Department of Defense Shale Oil Task Force. Volume 1. AD-A101-599/9. Department of Defense, Washington, D.C. 1978.

23. Bement, A. L. Statement on the Role of the Department of Defense in the Mobility Fuels Implementation of the Energy Security Act of 1980 by Dr. Arden L. Bement, DUSDRE(R/AT). Before the Subcommittee on Economic Stabilization of the Committee on Banking, Finance, and Urban Affairs of the House of Representatives 96th Congress, Second Session. AD-A101-583/3. Department of Defense, Washington, D.C. 1980.

24. Aiman, W. R. Why Solar Oil Shale Retorting Produces More Oil. UCID-19045. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

25. Badner, B. E. Oil Shale Program. Twentieth Quarterly Report. October 1980-December 1980. SAND-81-1038. Sandia National Laboratory, Albuquerque, N.M. 1981.

26. Thumann, A. (Editor) The Emerging Synthetic Fuel Industry. Energy Books. Association of Energy Engineers, Atlanta, Georgia. 1981.

27. Rothman, A. J. Lawrence Livermore National Laboratory Oil Shale Project. Quarterly Report, January-March 1981. UCID-16986-81-1. Lawrence Livermore National Laboratory, Livermore, CA. 1981.

28. Heistand, R. N., *et al*. Paraho Environmental Data. Part 1. Process Characterization. Part II. Air Quality. Part III. Water Quality. DOE/EV-0086. U. S. DOE, Washington, D.C. 1980.

29. Ackerman, F. J., *et al*. Oil Shale Project Small Retort Run Summary. Run 5-15. Addendum. Computer Tables. UCID-18282. (Rev. 1). Lawrence Livermore National Laboratory, Livermore, CA. 1981.

30. Frankenfeld, J. W. and W. F. Taylor. Fundamental Synthetic Fuel Stability Study. First Annual Report. May 1, 1979-April 30, 1981. Exxon Res. and Eng. Co., Linden, N.J. 1980.

31. Colorado School of Mines. Parameters Affecting the Characteristics of Oil Shale Derived Fuels. Colorado School of Mines. Research Institute, Golden, CO. 1981.

32. Institute of Gas Technology. Synthetic Fuels from U. S. Oil Shales: A Technical and Economic Verification of the Hytort Process. Annual Report, Oct. 1, 1979-Sept. 30, 1980. DOE/ET/14102-T1. U. S. DOE, Washington, D.C. 1981.

33. Hommert, P. J. and C. E. Tyner. Model Capabilities for In-Situ Oil Shale Recovery SAND-80-2572. Sandia National Labs, Albuquerque, N.M. 1981.

34. Bates, E. R. and T. L. Thoem (Editors). Environmental Perspective on the Emerging Oil Shale Industry. EPA-600/2-80-205a. U. S. EPA, Cincinnati, Ohio. 1980.

35. Bader, B. E. (Editor). Oil Shale Program Twentieth Quarterly Report: Oct. 1980 through Dec. 1980. SAND-81-1038. Sandia National Labs., Albuquerque, N.M. 1981.

36. Peterson, E. J., *et al*. Investigation of Occidental Oil Shale, Inc. Retort 3E Spent Shales. LA-8792-MS. Los Alamos National Laboratory, Los Alamos, N.M. 1981.

37. USGS (1979)---Edited by D. A. Rickert, *et al*. Synthetic Fuels Development: Earth-Science Considerations. U. S. Dept. of Interior, Geological Survey, Washington, D.C. 1979.

38. Dougan, P. M. BX In-Situ Oil Shale Project: Progress Report for Dec. 1, 1979 to Feb. 29, 1980. DOE/LC/10747-11. Equity Oil Co., Salt Lake City, Utah. 1980.

39. Dougan, P. M. BX In-Situ Oil Shale Project: Progress Report for Dec. 1, 1980 to Feb. 28, 1981. DOE/LC/10747-T1. Equity Oil Co., Salt Lake City, Utah. 1981.

40. Kronenberger, L., et al. The Impact of the Clean Air Act on Oil Shale Development: API Oil Shale Case Study Group Report. American Petroleum Institute, Washington, D.C. 1981.

41. DOE. Oil Shale Surface Retorting: Environmental Characterization Information Report. DOE/EP-0015. U. S. Dept. of Energy, Washington, D.C. 1981.

42. Paraho Environmental Data. Part 1. Process Characterization. DOE/EV-008G. Development Engineering, Inc., Rifle, CO. June 1980.

43. Synthetic Fuels From U. S. Oil Shales: A Technical and Economic Verification of the Hytort Process. DOE/ET/14102-1. Institute of Gas Technology, Chicago, IL. Nov. 1980.

44. Occidental Vertical Modified In-Situ Process for the Recovery of Oil From Oil Shale. Phase II. DOE/LC/10036-17. Occidental Oil Shale, Inc. Grand Junction, CO. Jan. 1981.

45. Investigation of the Geokinetics Horizontal In-Situ Oil Shale Retorting Process. DOE/LC/10787-72. Geokinetics, Inc., Concord, CA. Feb. 1981.

46. Rao, R. and A. T. McMain, Jr. 1170-MW(T) HTGR-PS/C Plant Application Study Report: Shale Oil Recovery Application. GA-A-16092. General Atomic Co., San Diego, CA. May 1981.

47. Raley, J. H. and J. H. Campbell. Oil Shale Project Run Summary, Small Retort Runs S-21 and S-23. UCID-19082. California Univ., Livermore, CA. 1981.

48. Lawrence Livermore National Laboratory Oil-Shale Project. UCID-16986-81-2. Lawrence Livermore National Lab.,CA. 1 Sept. 1981.

49. Hommert, P. J. and C. E. Tyner. Model Capabilities for In-Situ Oil Shale Recovery. SAND-80-2572. Sandia National Labs., Albuquerque, N.M. Jan. 1981.

50. Liuengstoem, F. F. Process And Arrangement For Extracting Oil From Shale. SAND-81-6002. February 1981.

TABLE B-2k. REFERENCES ON CONTROLS AND CONTROL COSTS

Subject matter	Ref. no.	Area of applicability GE	RM	OS	Space scale MI	LO	ME	RE	Time scale MI	HO	DA	SE	Comments on the references
Controls and Control Costs	1			X	X				X	X	X	X	Oil Shale Controls and Costs
	2	X			X				X	X	X	X	Metal Particulate Controls
	3	X			X				X	X	X	X	Control of NO_x
	4	X			X	X			X	X	X	X	NO_x Control Technologies for Stationary Sources (research project)
	5	X			X	X	X		X	X	X	X	Controlling Airborne Particles
	6			X	X	X			X	X	X	X	Environmental Control Technology for Oil Shale
	7	X			X				X	X	X	X	Controlling Residential Wood Combustion
	8	X			X	X			X	X	X	X	Controlling NO_x Sources
	9	X			X	X			X	X	X	X	Controlling NO_x Sources
	10	X			X				X	X	X	X	Controlling Fugitive Dust
	11	X			X	X	X		X	X	X	X	Minimizing the Cost of Air Pollution Control
	12	X			X				X	X	X	X	Controlling Fugitive Dust
	13	X			X				X	X	X	X	Controlling Fugitive Dust
	END	–	–	–	–	–	–	–	–	–	–	–	----

REFERENCES

k. Controls and Control Costs

1. Drabkin, M. and L. J. Duncan. Environmental Control Costs for Oil Shale Processes. MTR-79 W00218. The MITRE Corp., McLean, VA. 1979.

2. Peters, E. T., Jr., et al. Metal Particulate Emissions From Stationary Sources: Volume 2. Characteristics of Collection Filters. EPA-600/2-80-203. U. S. EPA, Research Triangle Park, N.C. 1980.

3. Manny, E. H. and A. R. Crawford. Control of Utility Boiler and Gas Turbine Pollutant Emissions by Combustion Modification - Phase II. EPA-600/7-81-039. U. S. EPA, Research Triangle Park, N.C. 1981.

4. Mason, H. B. and L. Waterland. Environmental Assessment of Stationary Source NO$_x$ Control Technologies. SSIE No. GMA-3357-2. U. S. EPA, Research Triangle Park, N.C. 1981.

5. National Research Council. Controlling Airborne Particles. National Academy of Sciences, Washington, D.C. 1980.

6. Nevers, N., et al. Analysis of the Environmental Control Technology for Oil Shale Development. COO/4043-1. U. S. DOE, Washington, D.C. 1978.

7. Hall, R. E. and D. G. DeAngelis. "EPA's Research Program for Controlling Residential Wood Combustion Emissions." APCA. J. 30. 1980. pp. 862-867.

8. Hayes, S. R. Control of Nitrogen Oxides: Assessment of Needs and Options, Technical Support Document. Volume 1, Introduction and Summary. EA-2048, Volume 1. Electric Power Research Institute, Palo Alto, CA. 1981.

9. Souten, D. R. and W. R. Oliver. Control of Nitrogen Oxides: Assessment of Needs and Options, Technical Support Document. Volume 2, Legislative and Regulatory Environment. EA-2048, Volume 2. Electric Power Research Institute, Palo Alto, CA. 1981.

10. Radkey, R. L. and P. B. MacCready. A Study of the Use of Porous Wind Fences to Reduce Fugitive Dust Transport at the Mohave Generating Station. TM-80/567. AeroVironment, Inc., Pasadena, CA. 1980.

11. Gass, G. R. and G. J. McRae. Minimizing the Cost of Air Pollution Control." Environ. Sci. and Tech. 15. 1981. pp. 748-757.

12. Yung, S. C., et al. "Spray Charging and Trapping Scrubber for Fugitive Particle Emission Control." APCA J. 30. 1980. pp. 1208-1211.

13. Mathai, C. V. A New Charged Fog Generator for Inhalable Particulate Control. AV-R-82/504. (Final Report Submitted to U. S. EPA). AeroVironment, Inc., Pasadena, CA. 1982.

TABLE B-21. REFERENCES ON SOCIAL IMPACTS (INCLUDING HUMAN HEALTH EFFECTS) and Population Growth

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Social Impacts and Population Growth	1		X	X		X	X					X	Population (county size)
	2	X	X				X	X				X	Energy Use and Supply
	3	X						X				X	National Energy Policy
	4	X						X				X	U.S.-Canadian Acid Rain Policies
	5			X		X	X	X				X	Bureau of Mines Research Plan
	6		X	X		X	X	X				X	Implications of Accelerated Synfuel Development
	7			X	X	X						X	Navy Oil Shale Reserves
	8		X		X	X						X	Health and Safety Problems (tight sands)
	9			X	X	X						X	Environmental and Health Impacts of Trace Elements
	10	X		X	X	X						X	Health Effects of Synfuel Development
	11	X				X					X	X	Allergenic Pollen in a Desert City
	12	X						X				X	National Energy Forecasts
	13	X						X				X	Forecast of Oil Prices
	14	X		X				X				X	Synfuel Market Potential
	15			X	X	X			X	X			Acute Toxicity of End Products
	16			X	X	X						X	Mutagenicity of Shale Oil
	17	X	X	X		X	X	X				X	Population Trends in U.S.
	18	X						X				X	World Oil Market Outlook
	19			X	X	X				X	X	X	Health Effects of Oil Shale Development
	20	X			X	X	X		X	X			Baseline Data for Inhalable Particulate Matter
	21			X	X	X	X					X	Policy Options of Development of Oil Shale
	22			X	X				X	X			Industrial Hygiene Concerns
	23			X	X				X	X	X	X	Toxicology of Oil Shale Materials

(continued)

TABLE B-21. (Continued)

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Social Impacts and Population Growth	24	X		X	X	X	X	X	X	X	X	X	Overall Impacts Analysis of Synfuels
	25			X	X	X	X					X	Federal Prototype Oil Shale Leasing Program
	26			X	X	X	X					X	Development of Oil Shale and Its Impacts
	27			X	X	X	X					X	Periodical About the Oil Shale Country
	28	X		X	X	X						X	Synthetic Fuels and Cancer.
	29			X	X	X	X					X	Synfuel Development in Uintah Basin
	30			X	X	X	X				X	X	Oil Shale Research Planning Meeting
	31	X		X	X	X	X					X	Status and Direction of Synfuel Development
	32	X		X	X	X	X					X	Status and Directions of Synfuel Development
	33	X			X	X				X	X		Comparison of Indoor/Outdoor Air Quality
	34	X			X					X	X		Workshop on Indoor Air Quality
	35			X	X	X						X	Financing Oil Shale Communities
	36			X	X	X						X	Chemistry and Mutagenicity of Shale Oil
	37			X	X	X					X	X	Treatment of Multivariate Health Problems
	38	X			X					X	X		Indoor Air Pollution From Combustion
	39	X			X					X	X		Indoor Air Quality
	40			X	X				X	X	X	X	Occupational Health in the Oil Shale Industry
	END	-	-	-	-	-	-	-	-	-	-	-	----

REFERENCES

ℓ. Social Impacts & Population Growth

1. Lane, H. U. (Editor). The World Almanac & Book of Facts 1981. Newspaper Enterprise Assoc., Inc., New York, N.Y. 1981.

2. EPRI. Overview and Strategy: 1981-1985 Research and Development Program Plan. Electric Power Research Institute, Palo Alto, CA. 1980.

3. U. S. DOE. Securing America's Energy Future: The National Energy Policy Plan. DOE/S-0008. U. S. Dept. of Energy, Washington, D.C. 1981.

4. Mulvaney, J. N. and D. W. Hadden. A Submission to the United States Environmental Protection Agency Opposing Relaxation of SO_2 Emission Limits in State Implementation Plans and Urging Enforcement. Ministry of the Environment, Toronto, Ontario, Canada. 1981.

5. Scott, F. G. and D. A. Lewis. Oil Shale Mining Environmental Research Program Plan: Vol. I - High Funding, Vol. II - Mid Funding, Vol. III - Low Funding Level. BUMINES-OFR-3(1,2,3)-81. Aerospace Corp., El Segundo, CA. 1980.

6. Loose, V. Some Implications of Accelerated Synthetic Fuels Development in the Rocky Mountain States. LA-8588-MS. Los Alamos Scientific Laboratory, Los Alamos, N.M. 1980.

7. U. S. DOE. Draft Programmatic Environmental Impact Statement: Development Policy Options. Naval Oil Shale Reserves. Garfield County, Colorado. DOE/EIS-0068. U. S. Dept. of Energy, Washington, D.C. 1980.

8. Riedel, E. F., et al. Assessment of Environmental Health and Safety Issues Associated with the Commercialization of Unconventional Gas Recovery: Tight Western Sands. PNL-3391. Pacific Northwest Laboratory, Richland, WA, 1980.

9. Chappell, W. R. Trace Elements in Oil Shale. Progress Report, 1976-1979. COO-4017-3. Colorado University, Boulder, CO. 1979.

10. Griest, W. H., et al. Repository Support of Synfuels Health Effects Research. CONF-810562-1. Oak Ridge National Laboratory, Oak Ridge, TN. 1981.

11. Solomon, A. M. and H. D. Hayes. "Impacts of Urban Development Upon Allergenic Pollen in a Desert City." J. Arid Environ. 3. 1980. pp. 169-178.

12. Malés, René. "Demand 80/81." EPRI Journal. Vol. 6. 1981. pp. 47-49.

13. Steward-Gordon, T. J. "What Price Oil." World Oil. Oct. 1981. pp. 39-46.

14. ESCOE. Synthetic Fuels Summary. DOE/ET/10679-T10. Engineering Societies Commission on Energy, Inc., Washington, D.C. 1981.

15. Parker, G. A., et al. Acute Toxicity of Conventional Versus Shale - Derived JP5 Jet Fuel: Light Microscopic, Hemotologic, and Serum Chemistry Studies. AFRRI-SR81-12. Armed Forces Radiobiology Research Institute, Bethesda, MD. 1980.

16. Guerin, M. R., et al. Chemistry and Mutogenicity of Shale Oil. CONF-810676-1. Oak Ridge National Laboratory, Oak Ridge, TN. 1981.

17. EEI. Electric Perspectives. Edison Electric Institute, Washington, D.C. Fall 1981.

18. U. S. DOE. World Oil Market Outlook: Recent History and Forecasts of World Oil Prices. DOE/EIA-0307. U. S. DOE, Washington, D.C. 1981.

19. Griest, W. G., et al. Health Effects Investigation of Oil Shale Development. Ann Arbor Science Publ., Inc., Woburn, MA. 1981.

20. Lioy, P. J., et al. "APCA Specialty Conference Workshop on Baseline Data for Inhalable Particulate Matter." APCA J. 30. 1980. pp. 1126-1130.

21. OTA. An Assessment of Oil Shale Technologies. OTA-M-118. Office of Technology Assessment, Washington, D.C. 1980.

22. Ettinger, H. J. "Industrial Hygiene Concerns Associated with Oil Shale Development." Oil Shale;the Environmental Challenges. Colorado School of Mines Press, Golden, CO. 1981. pp. 64-75.

23. Holland, L. M. "Studies of the Biology and Toxicology of Oil Shale Materials." Oil Shale: The Environmental Challenges. Colorado School of Mines Press, Golden, CO. 1981. pp. 87-104.

24. U. S. DOE. Synthetic Fuels and the Environment: An Environmental and Regulatory Impacts Analysis. DOE/EV-0087. U. S. DOE, Washington, D.C. 1980.

25. OTA. An Assessment of Oil Shale Technologies. Volume II: A History and Analysis of the Federal Prototype Oil Shale Leasing Program. OTA-M-119. Office of Technology Assessment, Washington, D.C. 1980.

26. Harvard University. Vulnerability Reduction Study. Coal and Synthetics (Section IIIa). Technical Appendix. Energy and Environmental Policy Center. Harvard University, Cambridge, MA. 1980.

27. Tracom Corp. Shale Country. Mountain Empire Publ. Division of Tracom, Corp., Denver, CO. 1975-1982.

28. Sauter, D. Y. Synthetic Fuels and Cancer: Emergency Task Force on Energy Options. Scientists Institute for Public Information, New York, N.Y. 1975.

29. BLM. Project Management Plan for Synfuels Development in the Uintah Basin Region. U. S. Bureau of Land Management, Salt Lake City, Utah. 1981.

30. Werbe, N. Minutes of Air Quality Research Meeting. Univ. of Colo. The DOE Oil Shale Task Force, Denver, CO. October 6, 1980.

31. Synthetic Fuels: Status and Directions. Volume 1. Sections 1-17. EPRI-WS-79-238. Electric Power Research Inst., Palo Alto, CA. May 1981.

32. Conference Proceedings: Synthetic Fuels-Status and Directions. EPRI-WS-79-238. Electric Power Research Inst., Palo Alto, CA. 1981.

33. Moschandreas, D. J. and J. Zabransky, et al. Comparison of Indoor and Outdoor Air Quality. EPRI-EA-1733. Geomet, Inc., Gaithersburg, MD. 1981.

34. Workshop on Indoor Air Quality Research Needs. CONF-801259. U. S. DOE Assistant Secretary for Conservation and Renewable Energy, Washington, D.C. 1980.

35. Financing Oil Shale Communities. Strategies For Private Developers. CONF-8104101. Lewin and Associates, Inc., Washington, D.C. 9 April 1981.

36. Guerin, M. R., C. H. Ho, T. K. Rao and J. L. Epler. Chemistry and Mutagemicity of Shale Oil. CONF-810676-1. Oak Ridge National Lab., Oak Ridge, TN. 1981.

37. Kland, M. J. Treatment of Multivariate Environmental and Health Problems Associated With Oil Shale Technology. LBL-11245. California Univ., Berkeley, CA. July 1980.

38. Traynor, G. W., M. G. Apte, J. R. Girman and C. D. Hollowell. Indoor Air Pollution From Domestic Combustion Appliances. LBL-12886. Lawrence Berkeley Lab., Berkeley, CA. June 1981.

39. Hollowell, C. D. Indoor Air Quality. LBL-12887. Lawrence Berkeley Lab., Berkeley, CA. June 1981.

40. Voelz, G. L., R. S. Grier and K. M. Hargis. Viewpoint on Occupational Health in the Oil-Shale Industry. LA-UR-81-2309. Los Alamos National Lab., Los Alamos, N.M. 1981.

TABLE B-2m. REFERENCES ON LITERATURE REVIEWS AND SUMMARIES OF PERTINENT ABSTRACTS

Subject matter	Ref. no.	Area of applicability			Space scale				Time scale				Comments on the references
		GE	RM	OS	MI	LO	ME	RE	MI	HO	DA	SE	
Literature Reviews and Abstracts	1	X	X			X	X	X		X	X	X	Meteorology Survey
	2	X	X			X	X	X			X	X	Acid Rain Survey
	3	X	X	X	X	X	X	X				X	Energy References
	4	X	X	X	X	X	X	X				X	Energy References
	5	X			X	X			X	X	X		Diesel Exhaust Emissions
	6	X			X	X	X	X	X	X	X	X	Biological and Environmental Sciences
	7	X				X	X	X			X	X	Environmental Effects of Acid Rain
	8	X						X				X	Carbon Cycles and Climate
	9	X		X				X				X	General Energy Information
	10			X				X				X	General Oil Shale Information
	11			X				X				X	General Oil Shale Information
	12	X		X		X	X			X	X		Report on PSD and Acid Rain
	13	X			X	X	X		X	X	X	X	Workshop Report on Air Quality Modeling
	14	X			X	X	X	X	X	X	X	X	EPA Data Index
	15	X			X	X	X	X	X	X	X	X	Energy Data Contacts Finder
	16	X		X				X				X	National Energy Information System
	END	-	-	-	-	-	-	-	-	-	-	-	----

REFERENCES

m. Literature Reviews & Abstracts

1. AGU. U. S. National Report 1975-1978. Papers in Meteorology. American Geophysical Union, Washington, D.C. 1979.

2. Dailey, N. S. and S. G. Winslow. Health and Environmental Effects of Acid Rain. An Abstracted Literature Collection, 1966-1979. NLM/TIRC-80/1. Toxicology Information Response Center, Oak Ridge, TN. 1980.

3. Blow, S. J., et al. Energy: An Annotated Selected Bibliography. NASA-TM-82364. National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. 1979.

4. Blow, S. J., et al. (1979b) Energy: An Annotated Selected Bibliography. NASA-TM-82365. National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. 1979.

5. NTIS. Diesel Exhaust Emissions. 1974-December, 1980 (Citations from the American Petroleum Institute Data Base). PB81-806416. National Technical Information Service, Springfield, VA. 1981.

6. Pfuderer, H. A. and J. B. Moody. ORNL Publications in Biological and Environmental Sciences. ORNL-5798. Oak Ridge National Laboratory, Oak Ridge, TN. 1981.

7. Dailey, N. S. and S. G. Winslow. Health and Environmental Effects of Acid Rain: An Abstracted Literature Collection 1966-1979; and An Abstracted Literature Collection 1979-1980. NLM/TIRC-80/1 and NLM/TIRC-81/1 (Update). Oak Ridge National Laboratory, Oak Ridge, TN. 1980 and 1981.

8. Olson, J. S., et al. Carbon Cycles and Climate: A Selected Bibliography-Volumes 1, 2, 3. ORNL/EIS-108/V1,V2,V3. Oak Ridge National Laboratory, Oak Ridge, TN. 1980.

9. U. S. DOE. Energy Information Directory (Formerly: Energy Information Referral Directory). First Quarter 1981. DOE/EIA-0205 (81/1Q). U. S. Dept. of Energy, Washington, D.C. 1981.

10. NTIS. Oil Shale Mining, Processing, Uses, and Environmental Impacts. 1978-July, 1981 (Citations from the NITS Data Base). National Technical Information Service, Springfield, VA. 1981.

11. NITS. Oil Shale Mining, Processing, Uses and Environmental Impacts. 1978-July, 1981. (Citations from the Engineering Index Data Base). National Technical Information Service, Springfield, VA. 1981.

12. NAS & NAE. On Prevention of Significant Deterioration of Air Quality Environmental Studies Board of the Commission on Natural Resources. National Academy of Sciences and National Academy of Engineers. National Academy Press, Washington, D.C. 1981.

13. U. S. EPA. Regional Workshops on Air Quality Modeling: A Summary Report. U. S. EPA, Research Triangle Park, N.C. 1981.

14. U. S. DOE. EPA Data Index: An Abstract Journal - First Supplement (July-December 1980). DOE/EIA-0233(80/2). U. S. DOE, Washington, D.C. 1981.

15. U. S. DOE. Energy Data Contacts Finder. DOE/EIA-0259(81/2Q). U. S. DOE, Washington, D.C. 1981.

16. U. S. DOE. National Energy Information System - Version 2. DOE/EIA-0299. U. S. DOE, Washington, D.C. 1981.

17. U. S. DOE. Oil Shale and Tar Sands: A Bibliography. DOE/TIC-3367 (Suppl. 1). U. S. DOE Tech. Info. Center, Oak Ridge, TN. 1981.

18. Hundemann, A. S. Remote Sensing Applied to Environmental Pollution Detection and Management 1964-July 1980. Update of NTIS/PS-76/0500. National Tech. Info. Service, Springfield, VA. 1980.

19. O'Neill, R. V., N. Gerguson and J. A. Watts. Bibliography of Mathematical Modeling in Ecology. EDEB/IBP-75/5. Oak Ridge National Lab., Oak Ridge, TN. Dec. 1977.

20. Adams, S. M., R. L. Jolley, J. S. Mattice and J. R. Trabalka. Ozone in Aquatic Systems: A Selected, Annotated Bibliography. Oak Ridge National Lab., Oak Ridge, TN. Oct. 1978.

APPENDIX C

MAPS OF LAND-SURFACE FORMS AND SELECTED TERRAIN PROFILES FOR THE GREEN RIVER FORMATION STUDY AREA

LAND-SURFACE FORM MAPS AND TERRAIN PROFILES

The land-surface form maps and the terrain profiles given in this appendix should be useful to the mesoscale, air quality modeler of the oil shale areas of Wyoming, Colorado, and Utah. The land-surface form maps can be used to determine terrain roughness, while the terrain profiles can be used in initial analyses of the interactions between terrain and the transport and diffusion of air pollutants. The sequence of figures and tables in this appendix are as follows:

- Figure C-1, shows the mesoscale domain defining the Green River Formation in relationship to the Rocky Mountain west.
- Figures C-2 to C-5, show the important towns and geographical features in the four state area (Wyoming, Colorado, Utah, Idaho).
- Table C-1, lists the notation used in the land-surface form maps in Figures C-6 to C-9. Again, these maps are for the four state area of Wyoming, Colorado, Utah and Idaho.
- Figure C-10, is a terrain contour map for the mesoscale domain defined in Figure C-1.
- Figures C-11, are terrain profiles across the domain in Figure C-10, for every 1/10° of latitude and with a smoothing grid of 10 Km.
- Figures C-12, are terrain profiles across the domain in Figure C-10, for every 1/10° of longitude and with a smoothing grid of 10 Km.
- Figure C-13, shows some of the geographic features in and around the oil shale areas of Utah and Colorado.
- Figure C-14, shows a six-mile township grid superimposed over Colorado's Piceance Basin oil shale area.
- Figures C-15, are terrain profiles along the township grid shown in Figure C-14, with a smoothing grid of 3 Km.

REFERENCES

C-1. D. L. Elliott and W. R. Barchet (1980). Wind Energy Resource Atlas: Volume 1 - The Northwest Region. PNL-3195 & WERA-1. Pacific Northwest Laboratory, Richland, WA.

C-2. S. R. Andersen, et al. (1981). Wind Energy Resource Atlas: Volume 8 - The Southern Rocky Mountain Region. PNL-3195 & WERA-8. Pacific Northwest Laboratory, Richland, WA.

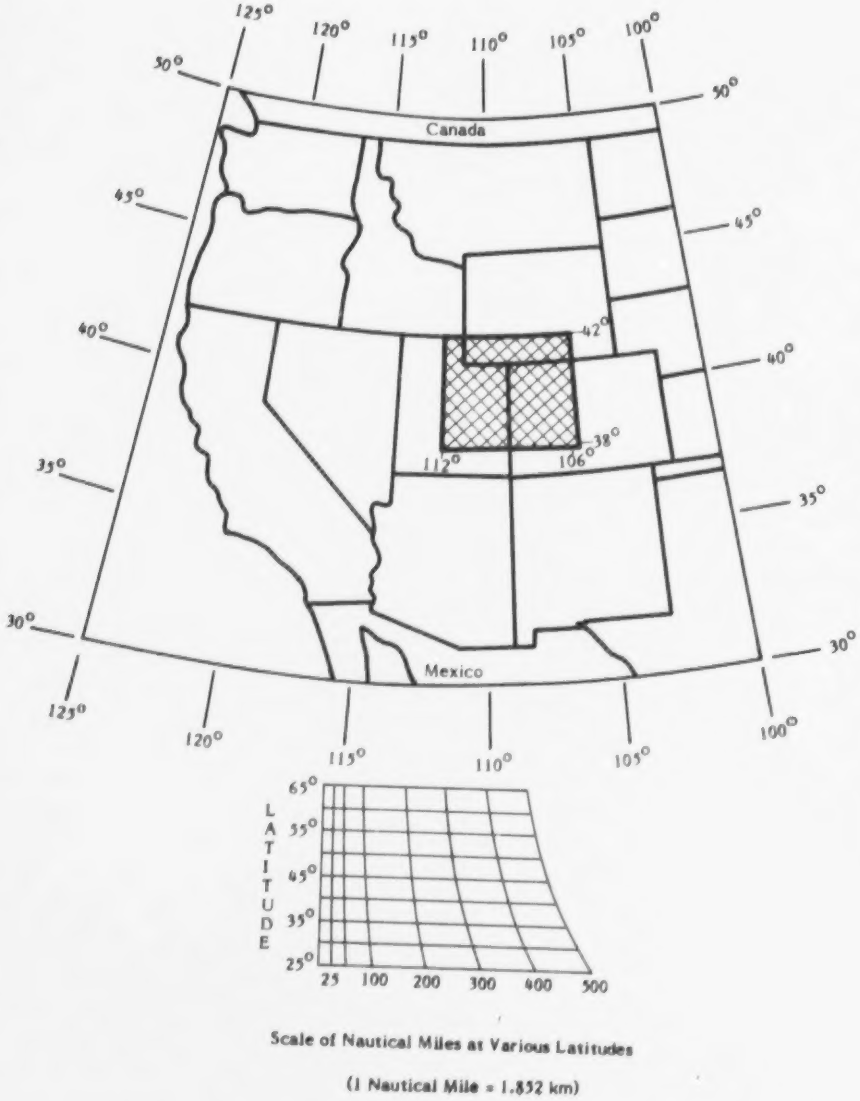

125°
120°
115°
110°
105°
100°
50°
45°
40°
35°
30°
Canada
Mexico
42°
38°
112°
106°
LATITUDE
65°
55°
45°
35°
25°
25
100
200
300
400
500
Scale of Nautical Miles at Various Latitudes
(1 Nautical Mile = 1.852 km)

Figure C-1. The mesoscale domain of computation (cross-hatched area) for the Green River Formation in relationship to the Rocky Mountain west.

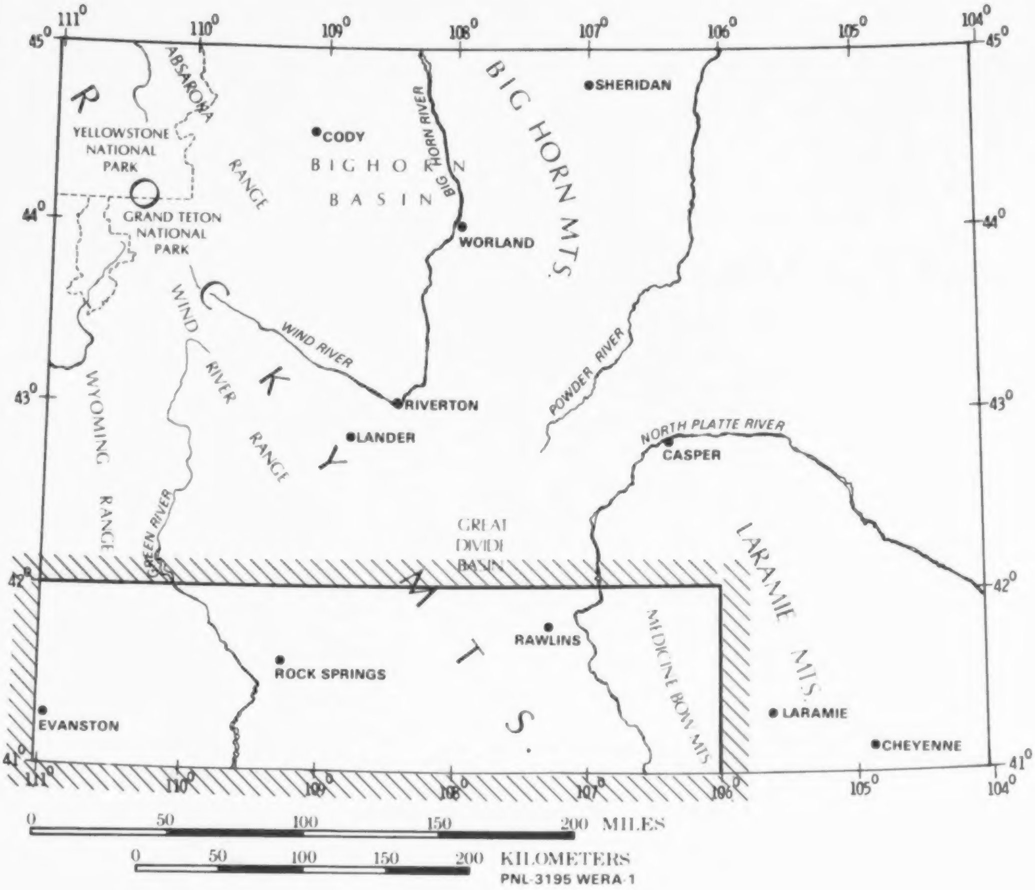

111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
R O C K Y M T S.
YELLOWSTONE NATIONAL PARK
GRAND TETON NATIONAL PARK
ABSAROKA RANGE
BIGHORN BASIN
BIG HORN RIVER
BIG HORN MTS.
SHERIDAN
CODY
WORLAND
WIND RIVER
WIND RIVER RANGE
WYOMING RANGE
RIVERTON
LANDER
POWDER RIVER
NORTH PLATTE RIVER
CASPER
GREEN RIVER
GREAT DIVIDE BASIN
LARAMIE MTS.
MEDICINE BOW MTS
RAWLINS
ROCK SPRINGS
EVANSTON
LARAMIE
CHEYENNE
0 50 100 150 200 MILES
0 50 100 150 200 KILOMETERS
PNL-3195 WERA-1

Figure C-2. Geographic map of Wyoming, showing Wyoming's contribution to the mesoscale domain in Figure C-1, [C-1].

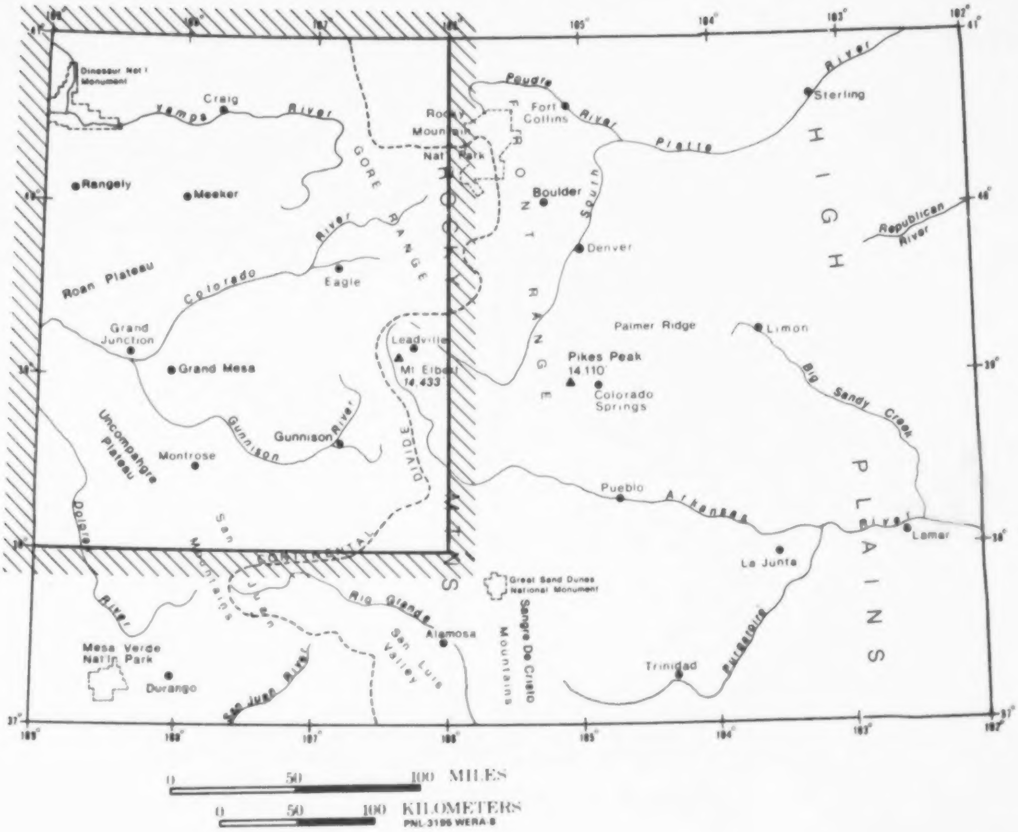

Dinosaur Nat'l Monument
Craig
Yampa River
Rangely
Meeker
Roan Plateau
Colorado River
Eagle
Grand Junction
Grand Mesa
Uncompahgre Plateau
Montrose
Gunnison River
Gunnison
Dolores River
San Juan Mountains
Mesa Verde Nat'l Park
Durango
San Juan River
GORE RANGE
ROCKY MTS
Rocky Mountain Nat'l Park
Leadville
Mt Elbert 14,433
CONTINENTAL DIVIDE
Rio Grande
Alamosa
San Luis Valley
Great Sand Dunes National Monument
Sangre De Cristo Mountains
FRONT RANGE
Fort Collins
Poudre River
South Platte River
Boulder
Denver
Palmer Ridge
Pikes Peak 14,110
Colorado Springs
Pueblo
Arkansas River
La Junta
Lamar
Purgatoire
Trinidad
Sterling
HIGH PLAINS
Republican River
Limon
Big Sandy Creek
41°
40°
39°
38°
37°
109°
108°
107°
106°
105°
104°
103°
102°
0 50 100 MILES
0 50 100 KILOMETERS
PNL-3196 WERA-8

Figure C-3. Geographic map of Colorado, showing Colorado's contribution to the mesoscale domain in Figure C-1, [C-2].

TYPING GUIDE SHEET

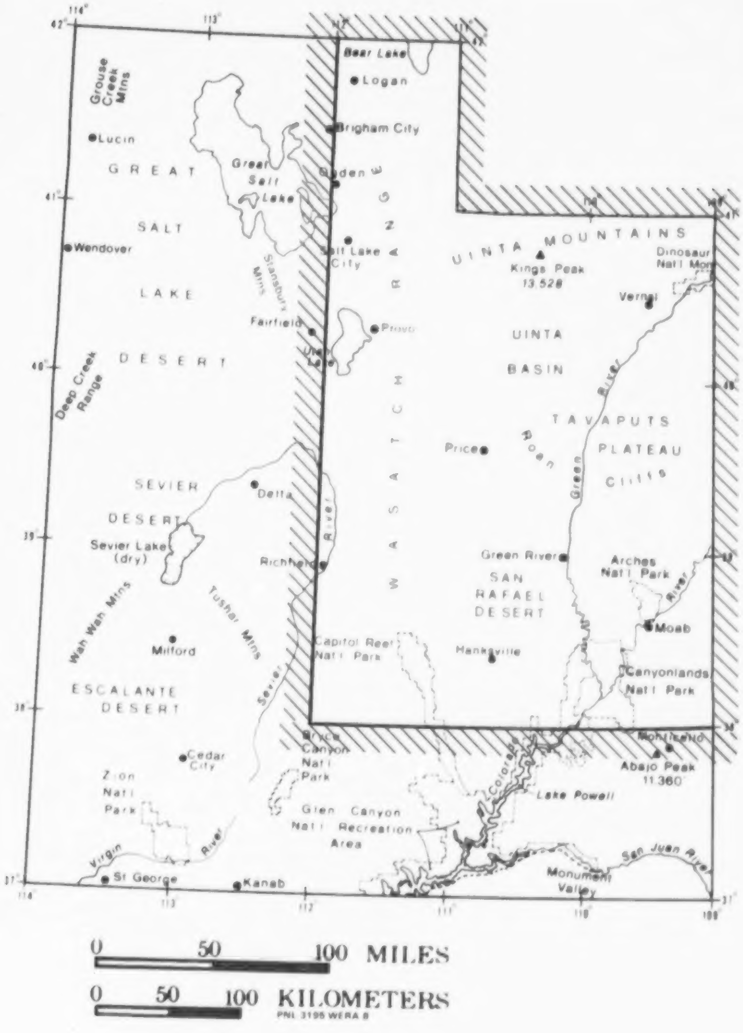
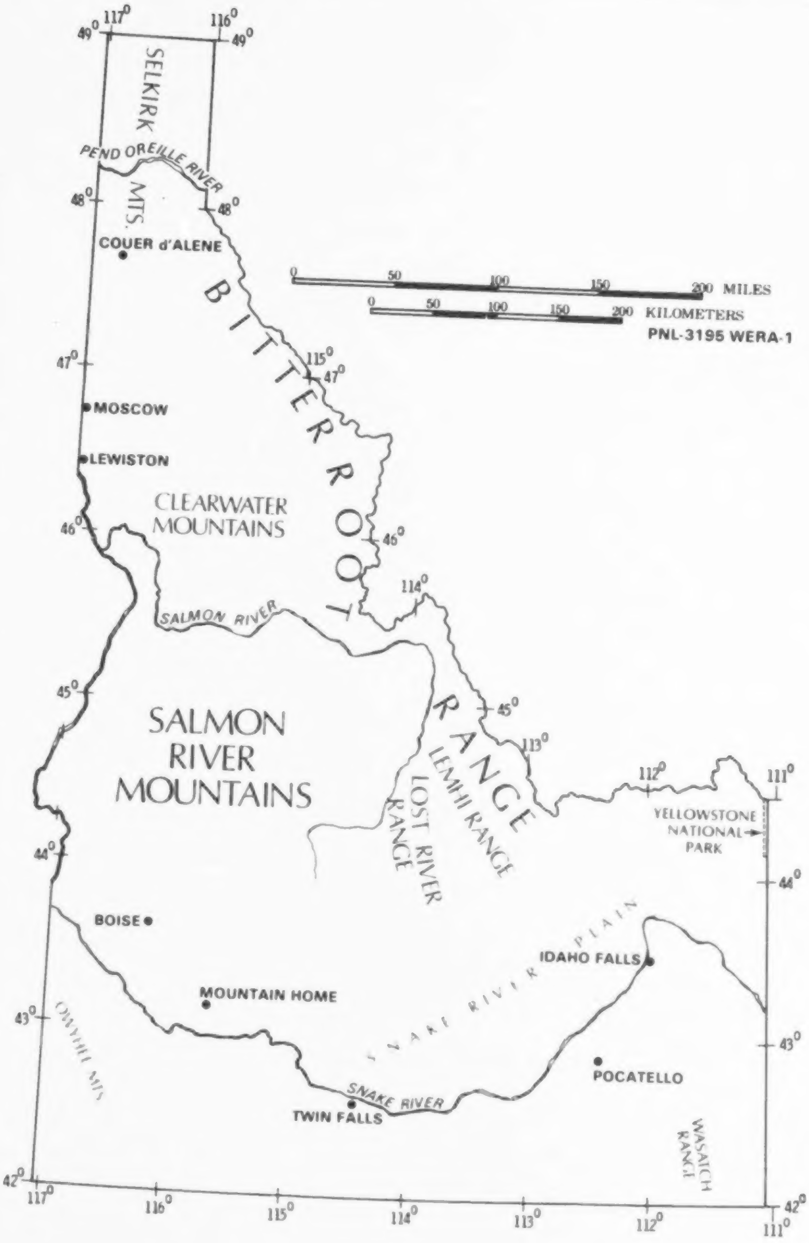

114°
113°
112°
111°
110°
109°
42°
41°
40°
39°
38°
37°
Bear Lake
Logan
Grouse Creek Mtns
Lucin
Brigham City
GREAT
Great Salt Lake
Ogden
SALT
Wendover
Salt Lake City
Stansbury Mtns
LAKE
Fairfield
Provo
Utah Lake
DESERT
Deep Creek Range
WASATCH RANGE
UINTA MOUNTAINS
Kings Peak 13,528
Dinosaur Nat'l Mon
Vernal
UINTA BASIN
TAVAPUTS PLATEAU
Roan Cliffs
Price
Green River
SEVIER DESERT
Delta
Sevier Lake (dry)
Sevier River
Richfield
Wah Wah Mtns
Tushar Mtns
Milford
Green River
SAN RAFAEL DESERT
Arches Nat'l Park
Moab
Capitol Reef Nat'l Park
Hanksville
Canyonlands Nat'l Park
ESCALANTE DESERT
Bryce Canyon Nat'l Park
Monticello
Abajo Peak 11,360
Cedar City
Zion Nat'l Park
Glen Canyon Nat'l Recreation Area
Colorado
Lake Powell
Virgin River
St George
Kanab
Monument Valley
San Juan River
0 50 100 MILES
0 50 100 KILOMETERS
PNL 3195 WERA 8

Figure C-4. Geographic map of Utah, showing Utah's contribution to the mesoscale domain in Figure C-1, [C-2].



49°
117°
116°
49°
SELKIRK MTS.
PEND OREILLE RIVER
48°
48°
COUER d'ALENE
BITTER ROOT RANGE
0 50 100 150 200 MILES
0 50 100 150 200 KILOMETERS
PNL-3195 WERA-1
47°
115°
47°
MOSCOW
LEWISTON
CLEARWATER MOUNTAINS
46°
46°
114°
SALMON RIVER
45°
45°
SALMON RIVER MOUNTAINS
113°
LEMHI RANGE
LOST RIVER RANGE
112°
111°
YELLOWSTONE NATIONAL PARK
44°
44°
BOISE
SNAKE RIVER PLAIN
IDAHO FALLS
MOUNTAIN HOME
43°
OWYHEE MTS
43°
POCATELLO
SNAKE RIVER
TWIN FALLS
WASATCH RANGE
42°
117°
116°
115°
114°
113°
112°
111°
42°

Figure C-5. Geographic map of Idaho, [C-1].

TABLE C-1. Land-surface form legend used in Figures C-6 to C-9, [C-1].

LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50 80% OF AREA GENTLY SLOPING
C	20 50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50 75% OF GENTLE SLOPE IS IN LOWLAND
c	50 75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

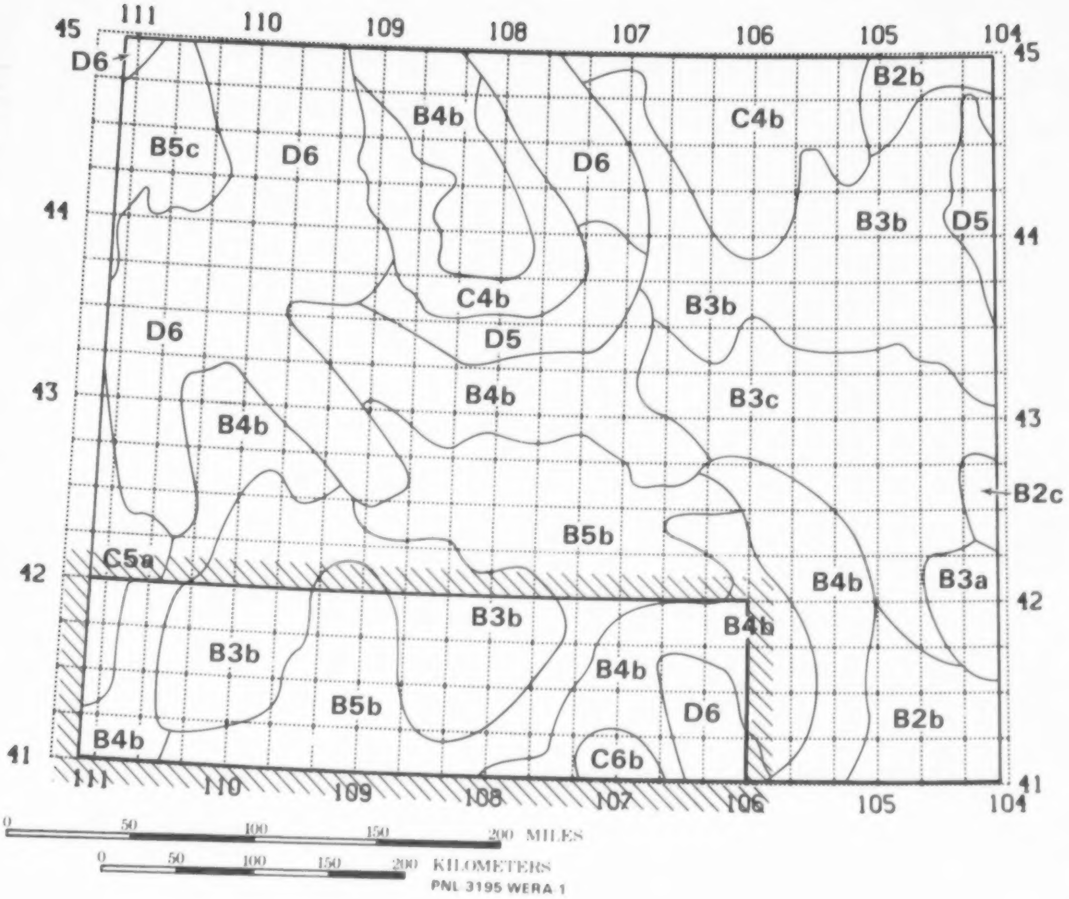

45
111
110
109
108
107
106
105
104
45
D6
B2b
B4b
C4b
B5c
D6
D6
44
B3b
D5
44
C4b
B3b
D6
D5
43
B4b
B3c
43
B4b
B2c
B5b
C5a
42
B4b
B3a
42
B3b
B4b
B3b
B4b
B5b
D6
B2b
41
B4b
C6b
41
111
110
109
108
107
106
105
104
0
50
100
150
200 MILES
0
50
100
150
200 KILOMETERS
PNL 3195 WERA-1

Figure C-6. Land-surface form map of Wyoming, showing Wyoming's contribution to the mesoscale domain in Figure C-1, [C-1].

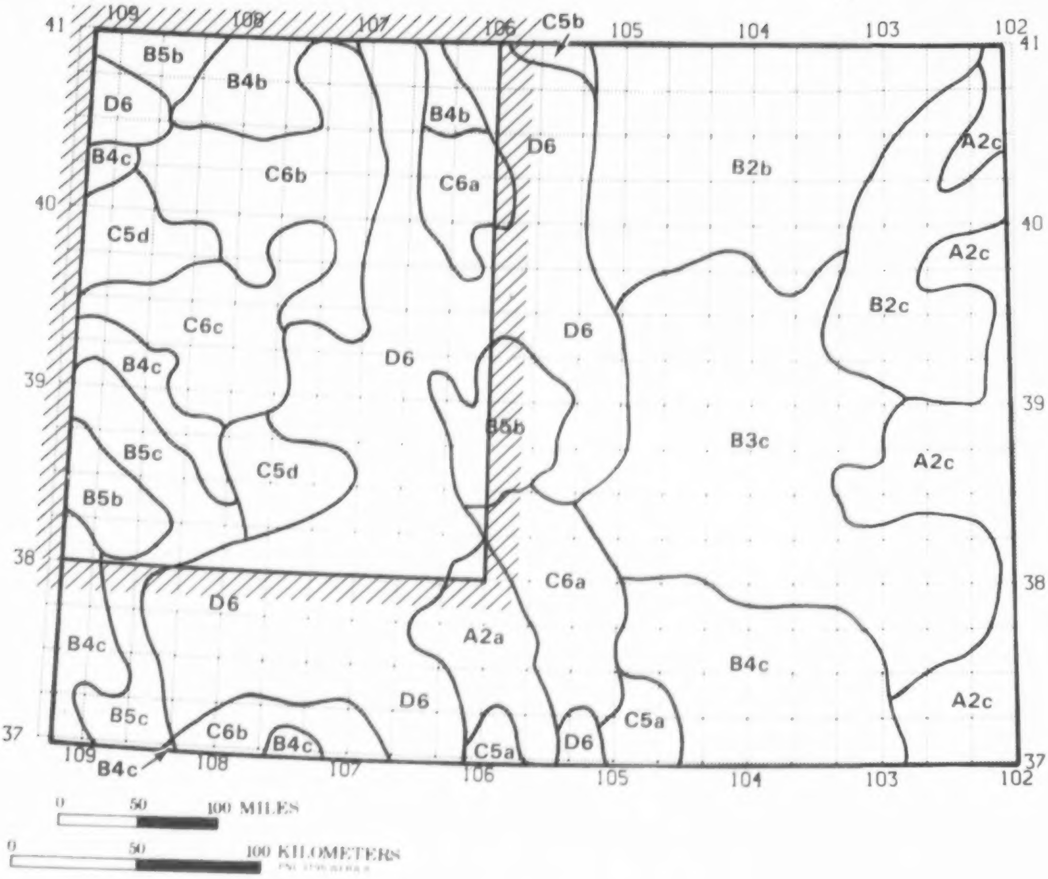

41
109
108
107
106
C5b
105
104
103
102
41
B5b
B4b
D6
B4b
D6
B4c
C6b
C6a
B2b
A2c
40
C5d
40
A2c
B2c
C6c
D6
D6
39
B4c
B5b
39
B3c
B5c
C5d
A2c
B5b
38
C6a
38
D6
B4c
A2a
B4c
D6
37
B5c
A2c
C6b
B4c
D6
C5a
109
B4c
108
107
C5a
106
105
104
103
37
102
0
50
100 MILES
0
50
100 KILOMETERS

Figure C-7. Land-surface form map of Colorado, showing Colorado's contribution to the mesoscale domain in Figure C-1, [C-2].

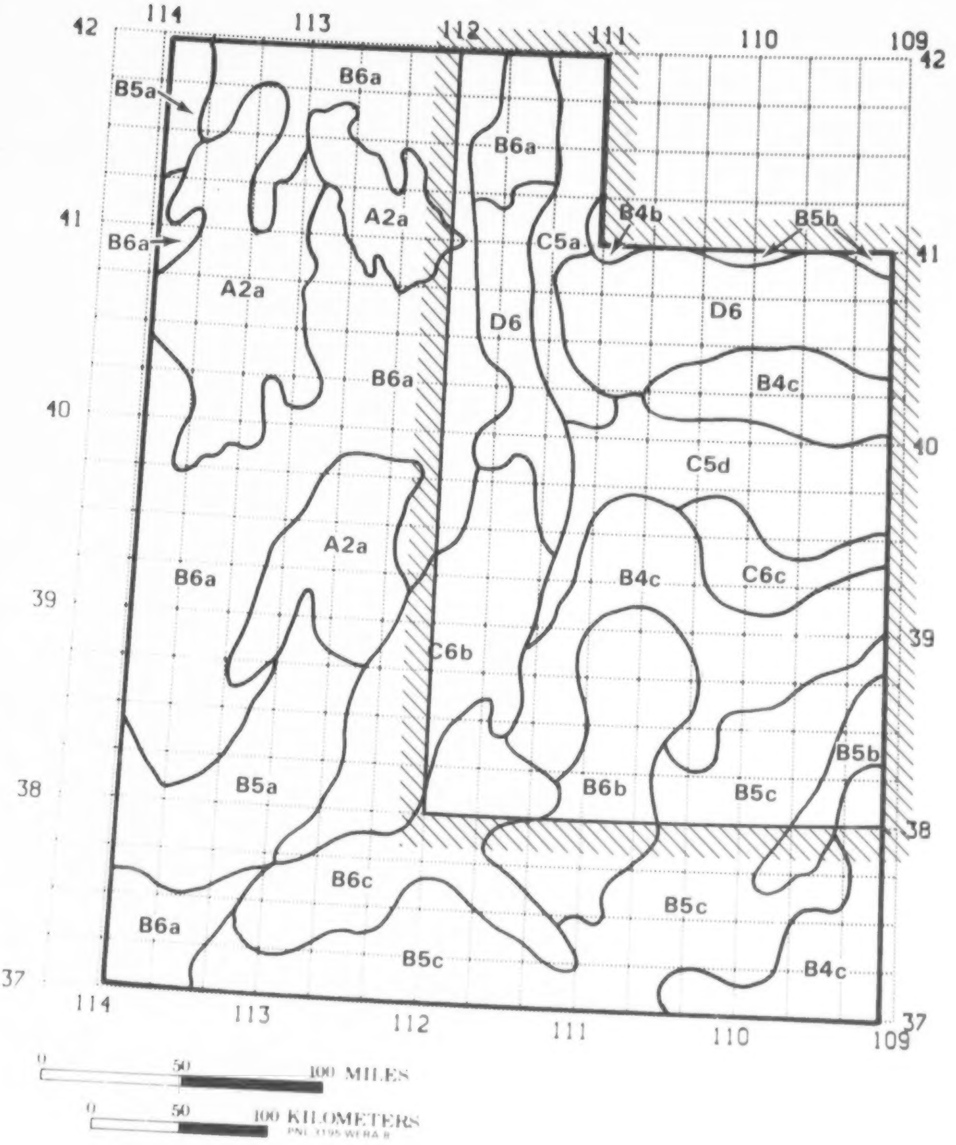
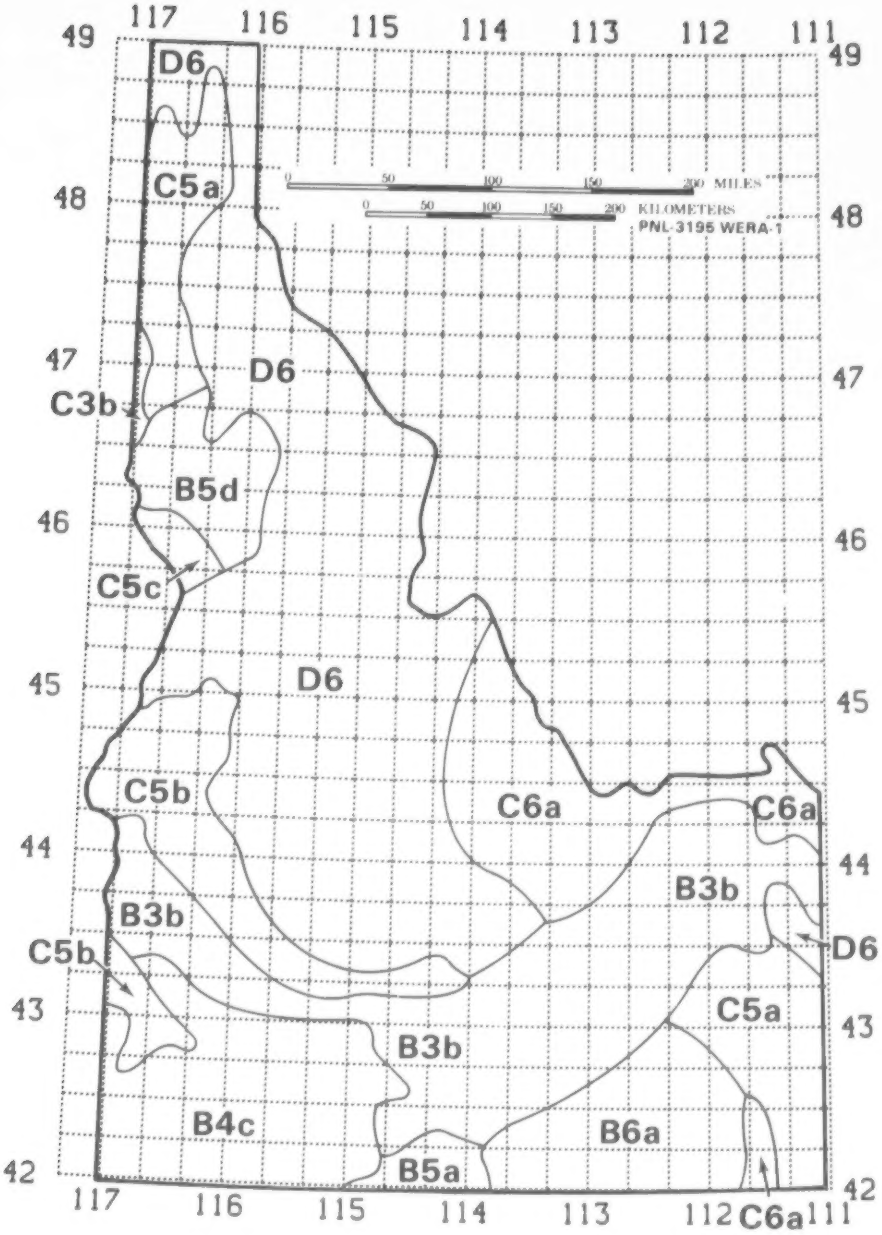

42
114
113
112
111
110
109
42
B5a
B6a
B6a
A2a
41
B6a
B4b
B5b
C5a
41
A2a
D6
D6
B6a
B4c
40
40
C5d
A2a
B6a
B4c
C6c
39
39
C6b
B5b
38
B5a
B6b
B5c
38
B6c
B5c
B6a
B5c
B4c
37
37
114
113
112
111
110
109
0
50
100 MILES
0
50
100 KILOMETERS
PNL 3195 WERA 8

Figure C-8. Land-surface form map of Utah, showing Utah's contribution to the mesoscale domain in Figure C-1, [C-2].



117
116
115
114
113
112
111
49
48
47
46
45
44
43
42
0
50
100
150
200 MILES
0
50
100
150
200 KILOMETERS
PNL-3196 WERA-1
D6
C5a
D6
C3b
B5d
C5c
D6
C5b
C6a
C6a
B3b
B3b
C5b
D6
C5a
B3b
B4c
B6a
B5a
C6a

Figure C-9. Land-surface form map of Idaho, [C-1].

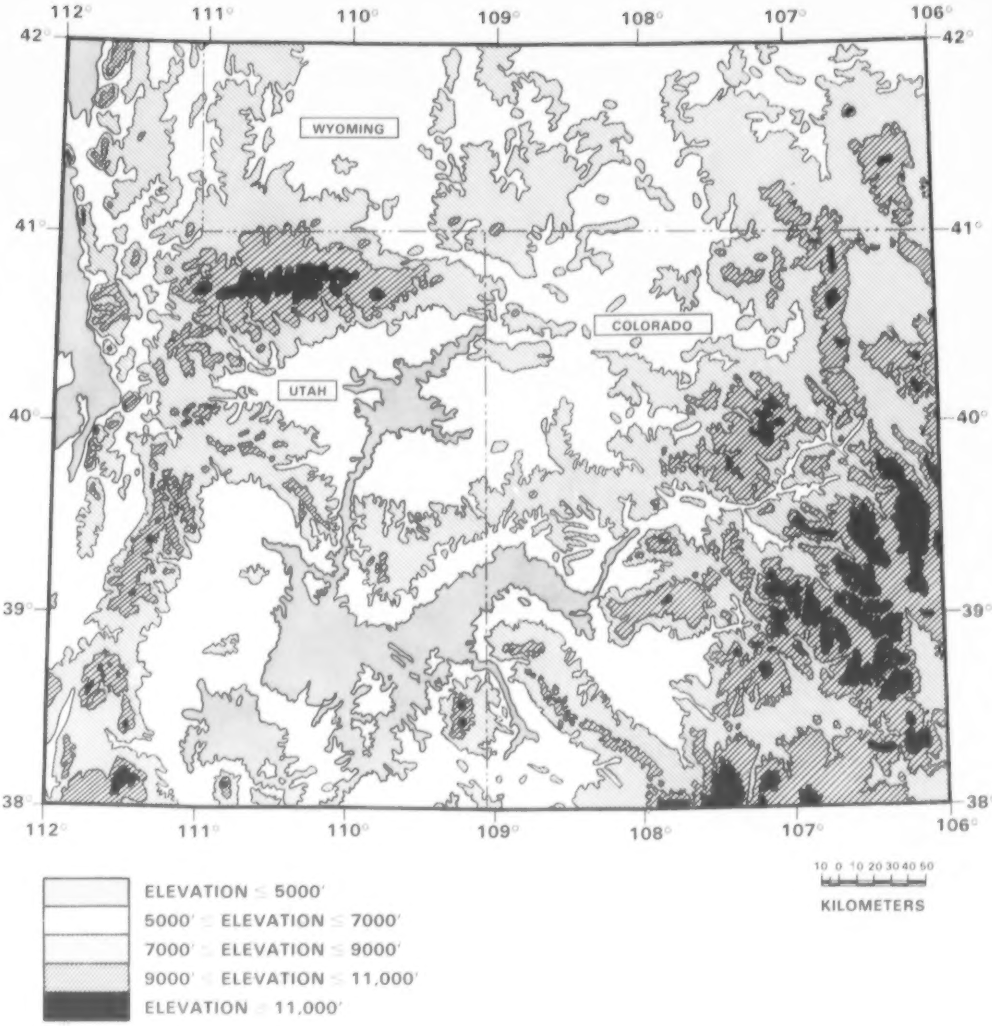

112°
111°
110°
109°
108°
107°
106°
42°
41°
40°
39°
38°
WYOMING
COLORADO
UTAH
ELEVATION ≤ 5000′
5000′ ≤ ELEVATION ≤ 7000′
7000′ ≤ ELEVATION ≤ 9000′
9000′ ≤ ELEVATION ≤ 11,000′
ELEVATION ≥ 11,000′
10 0 10 20 30 40 50
KILOMETERS

Figure C-10. The terrain contour map for the mesoscale domain in Figure C-1, with a contour interval of 2000 feet.

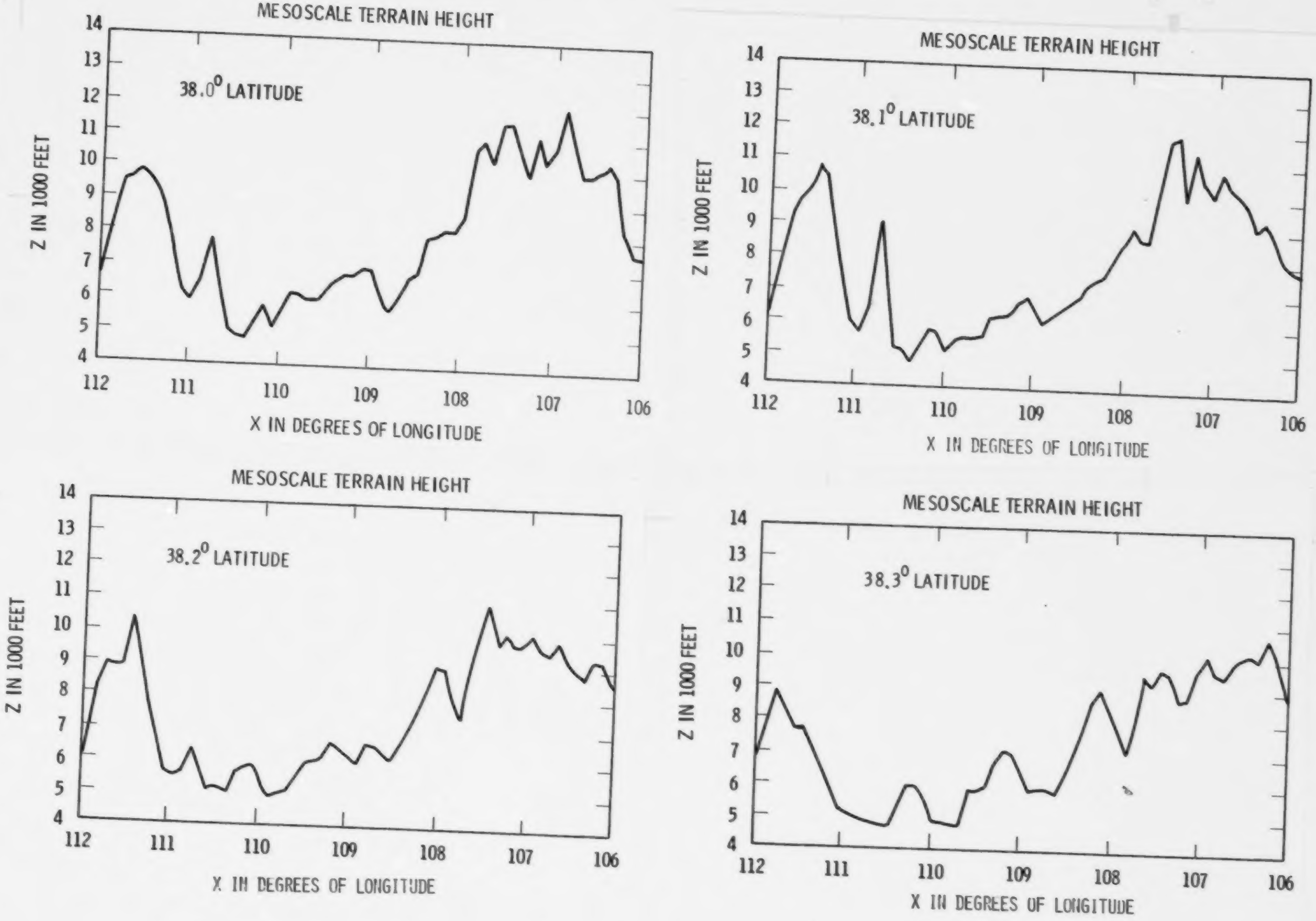


Figure C-11. Terrain profiles across the domain in Figure C-10, for every 1/10° of latitude and with a smoothing grid of 10 Km.

EPA Form 2200-4 (4-80)
(PREVIOUSLY CIB-EPA FORM 247)
TYPING GUIDE SHEET

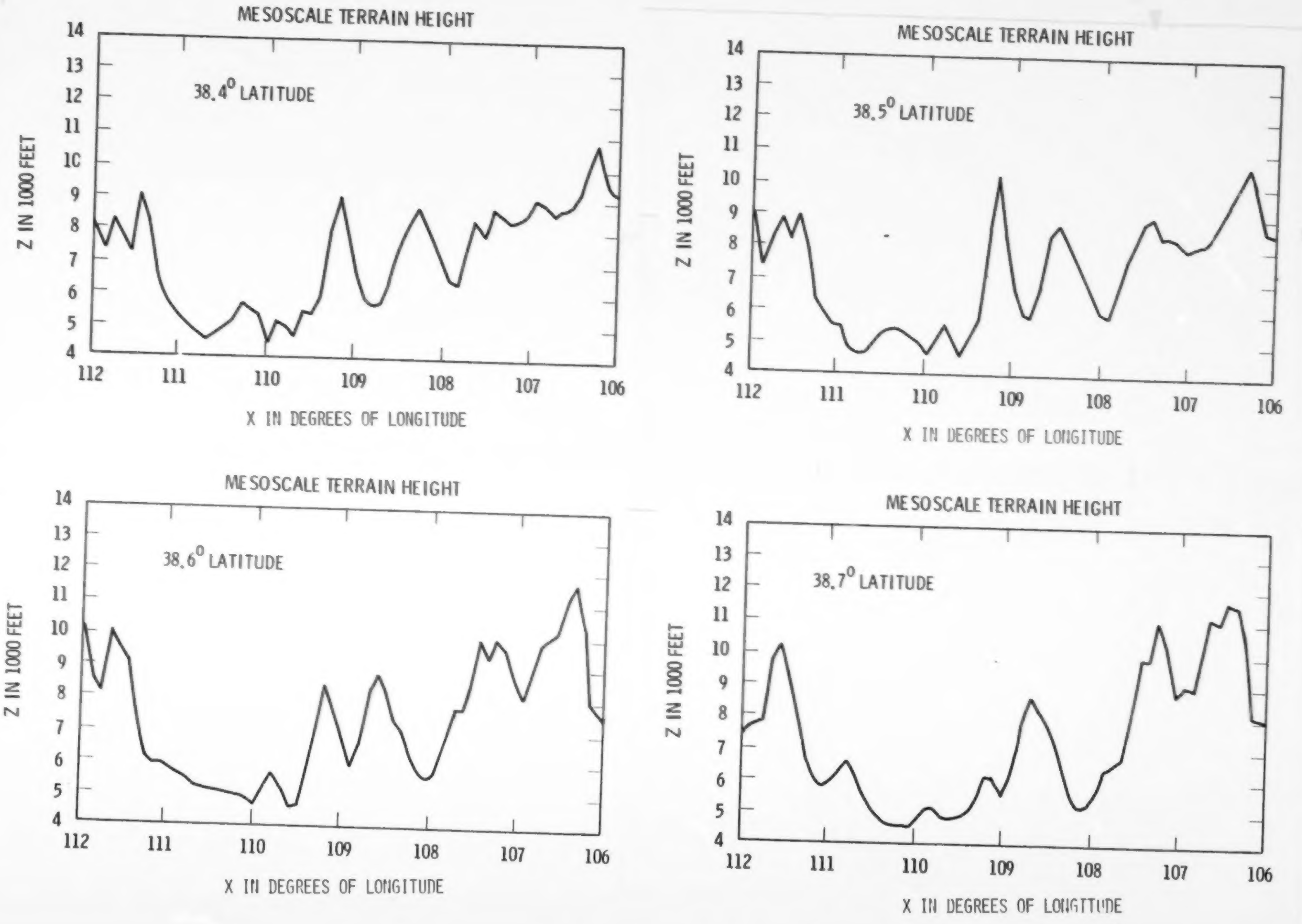


Figure C-11, continued

EPA Form 2200-8 (4-80)
TYPING GUIDE SHEET

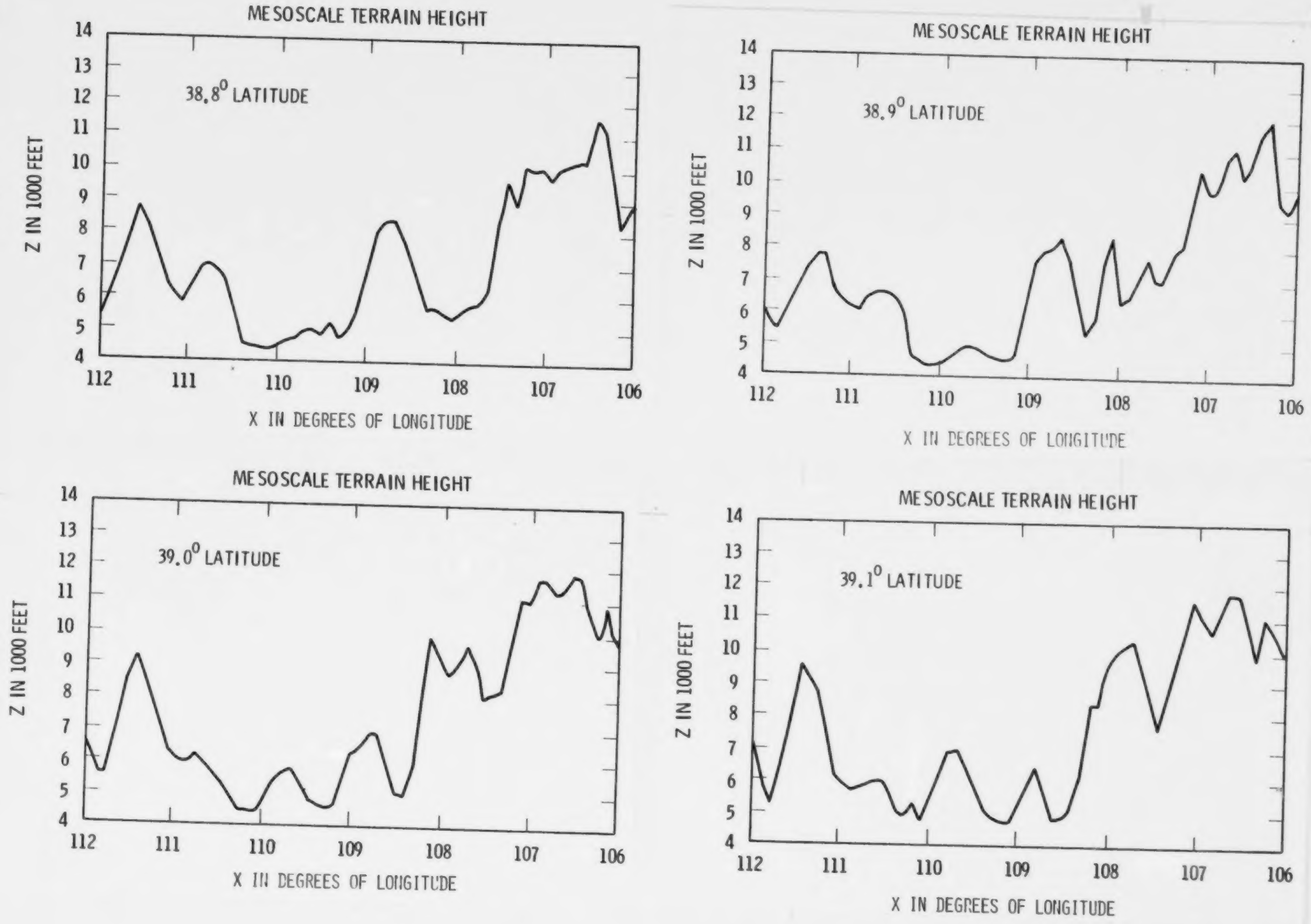


Figure C-11, continued.

TYPING GUIDE SHEET

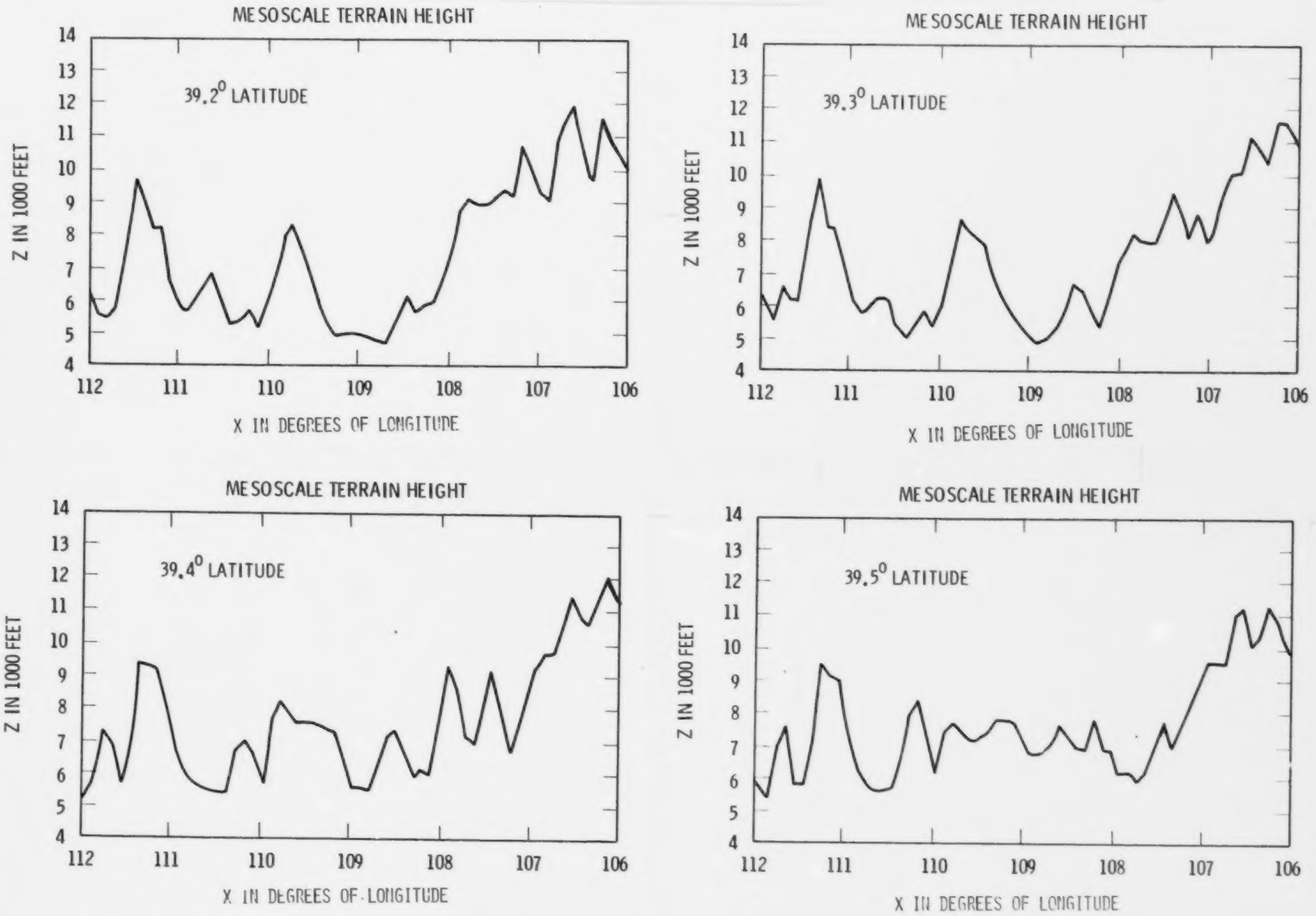


Figure C-11, continued.

TYPING GUIDE SHEET

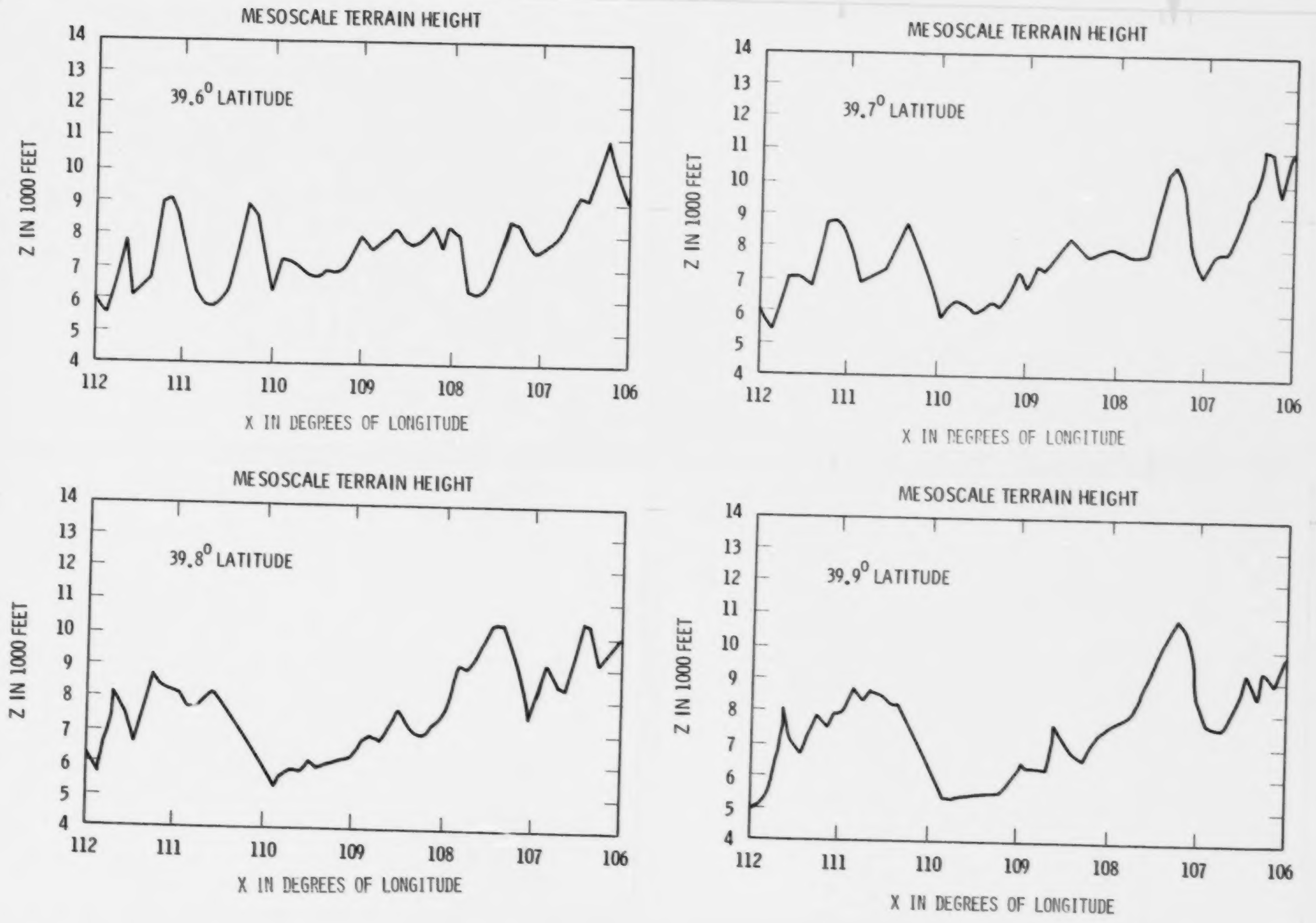


Figure C-11, continued.

EPA Form 2350-6 (1-80)
TYPING GUIDE SHEET

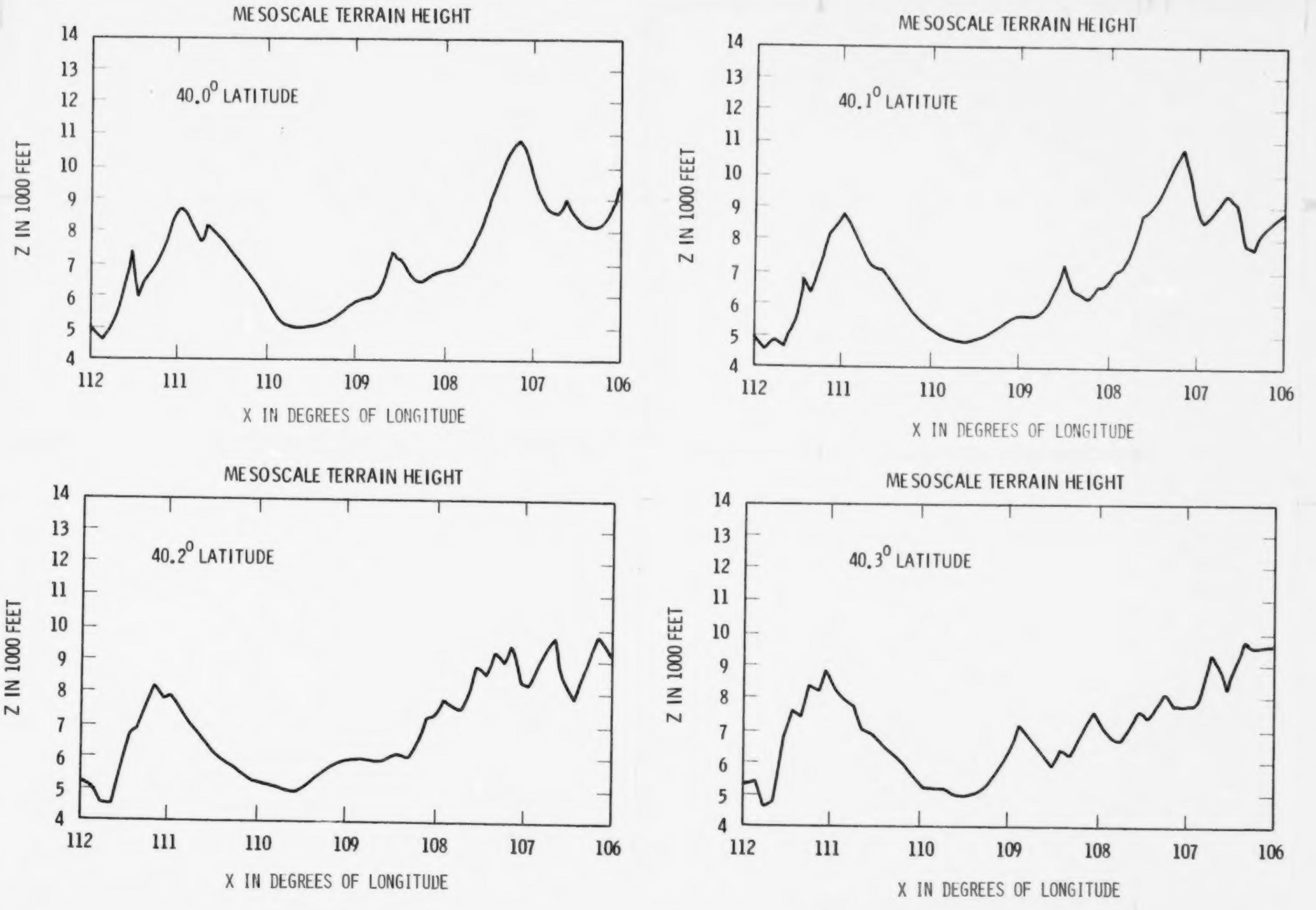


Figure C-11, continued.

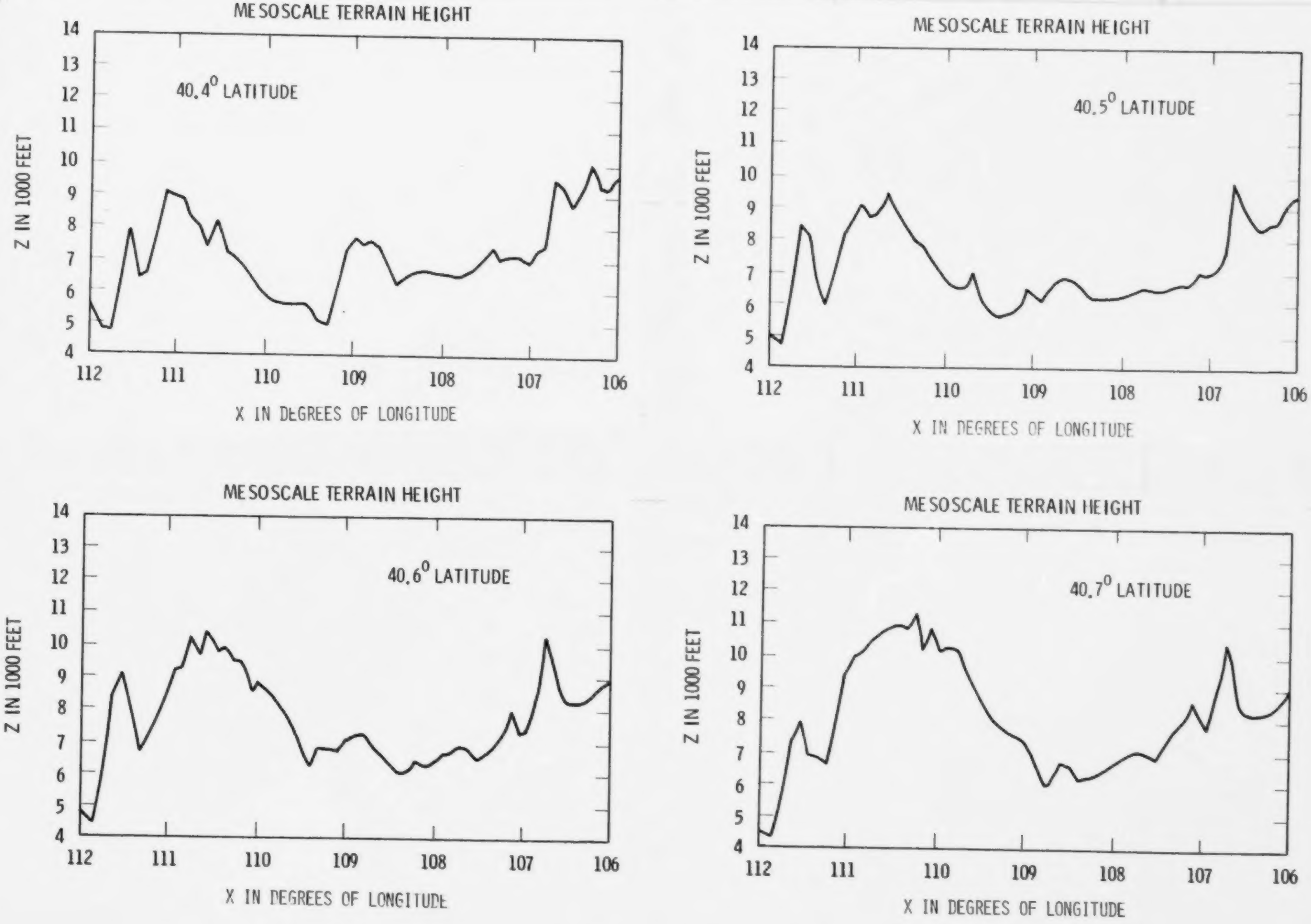
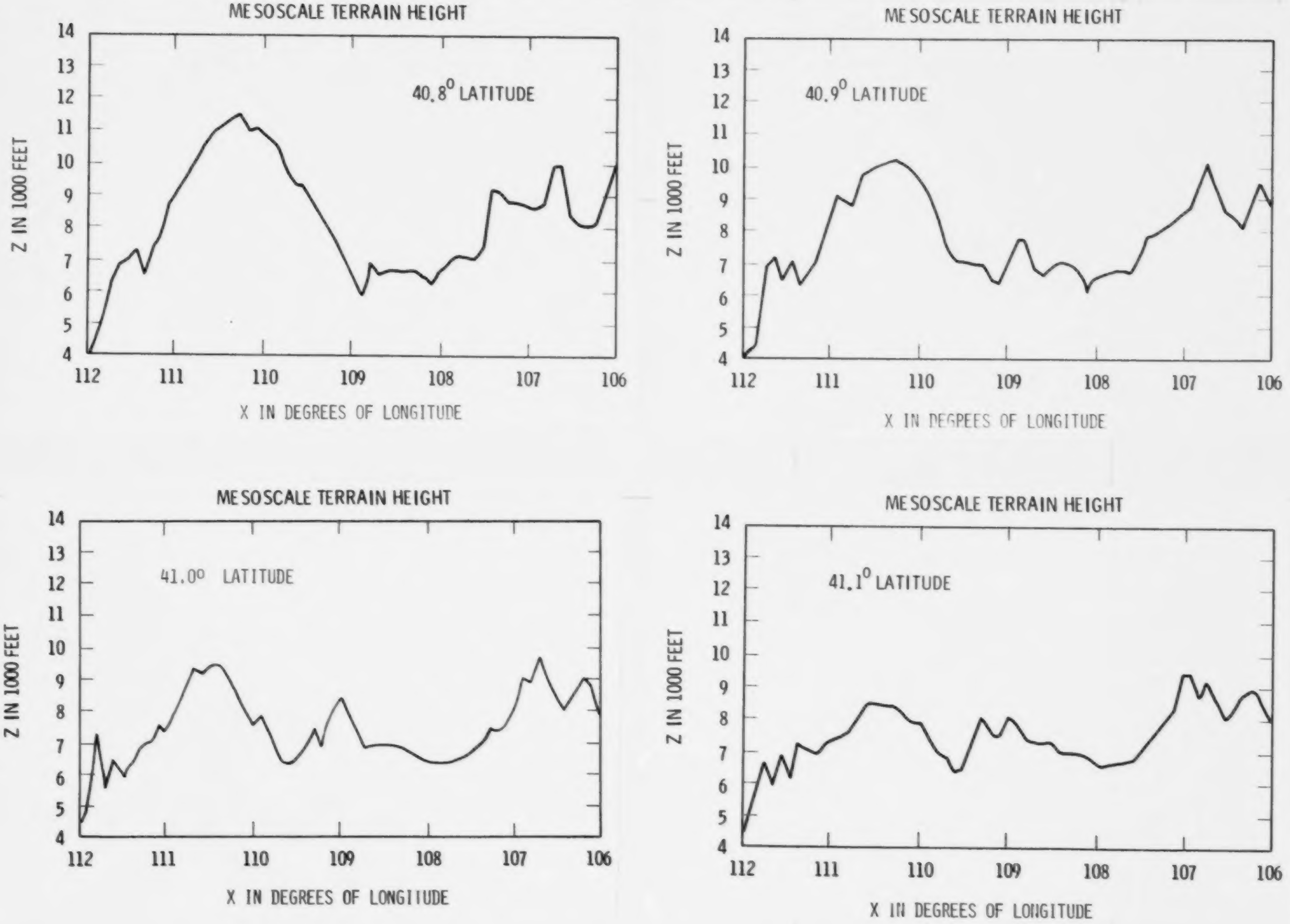


Figure C-11, continued.



MESOSCALE TERRAIN HEIGHT

40.8° LATITUDE

MESOSCALE TERRAIN HEIGHT

40.9° LATITUDE

MESOSCALE TERRAIN HEIGHT

41.0° LATITUDE

MESOSCALE TERRAIN HEIGHT

41.1° LATITUDE

Figure C-11, continued.

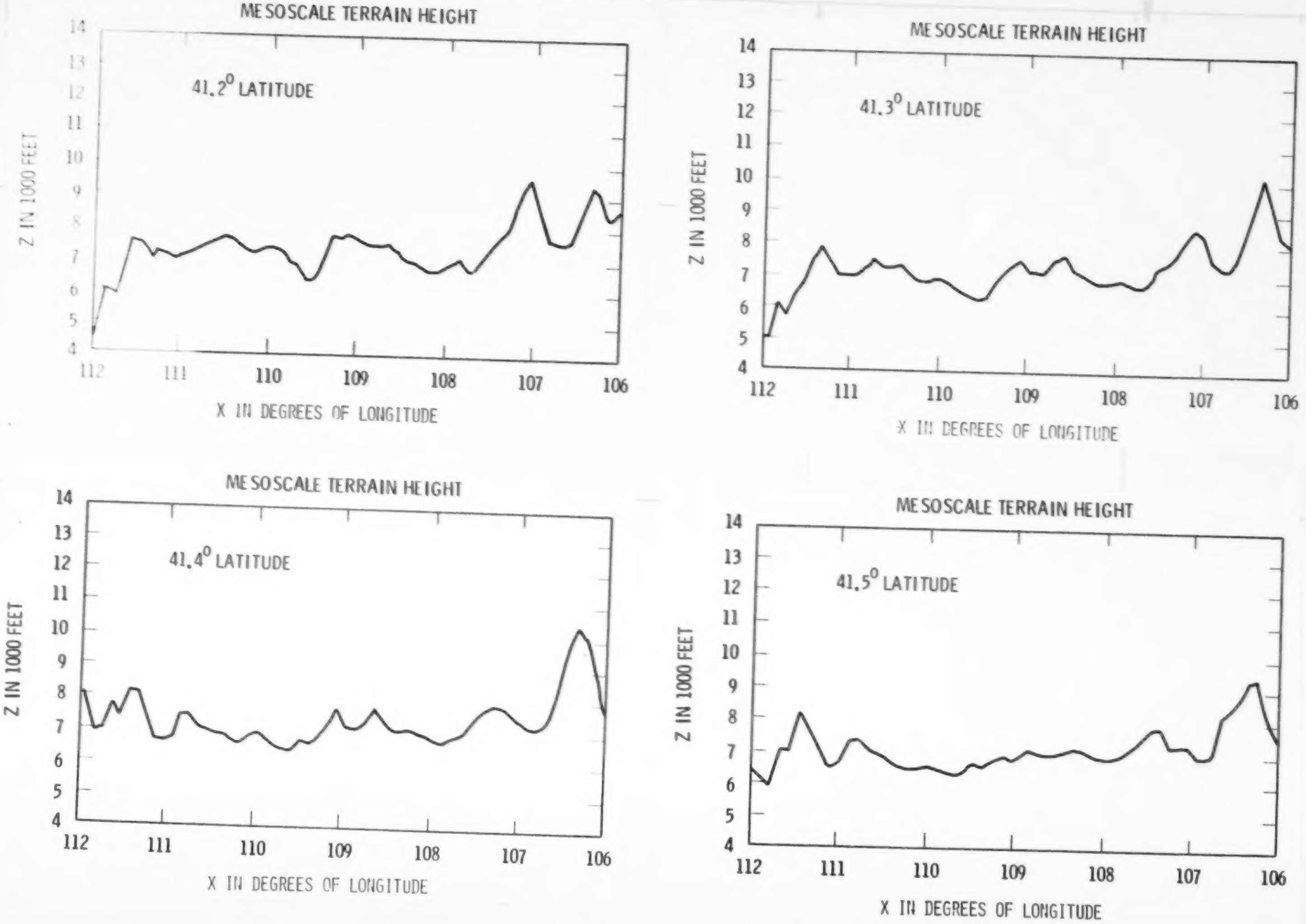


Figure C-11, continued.

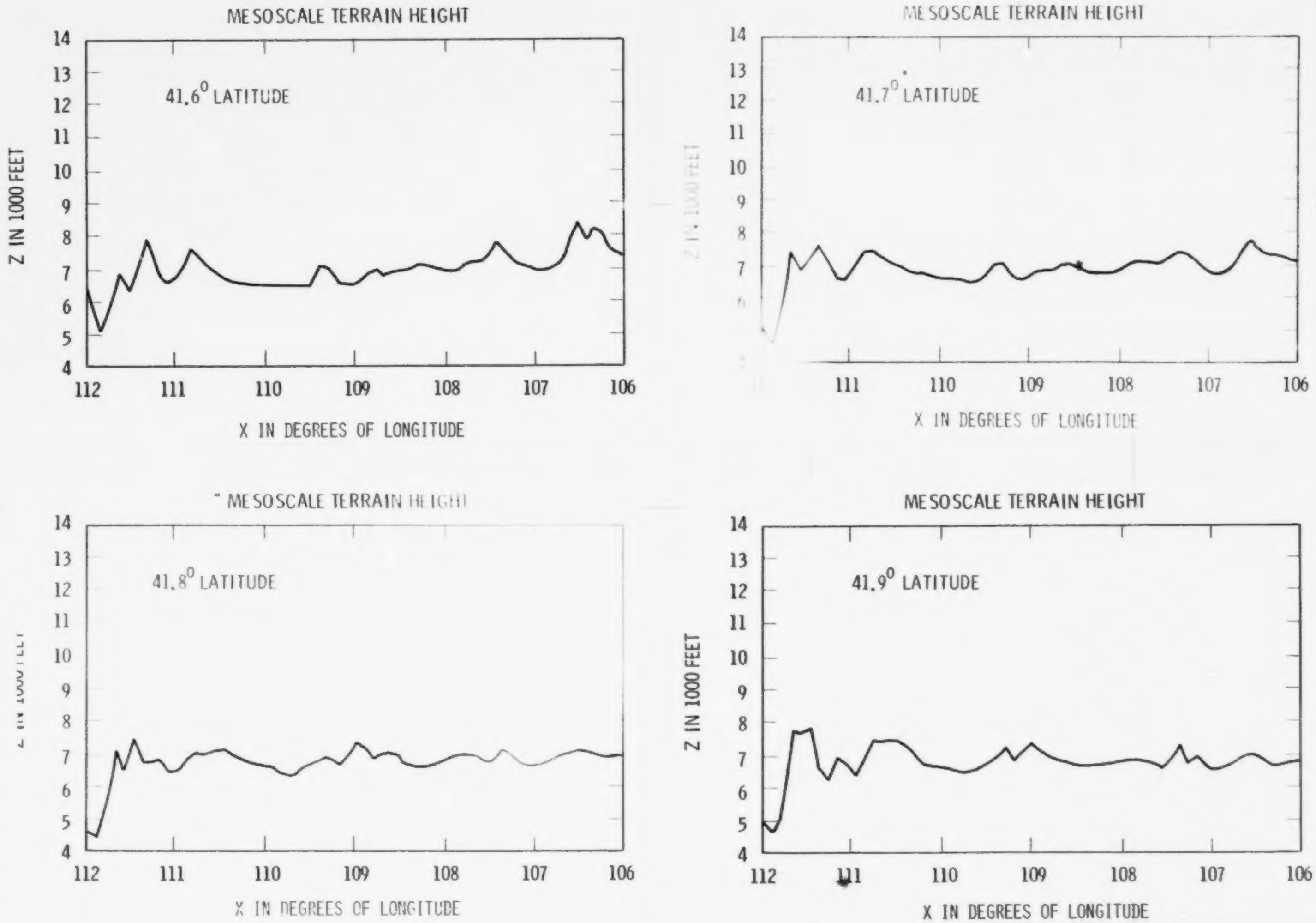


Figure C-11, continued

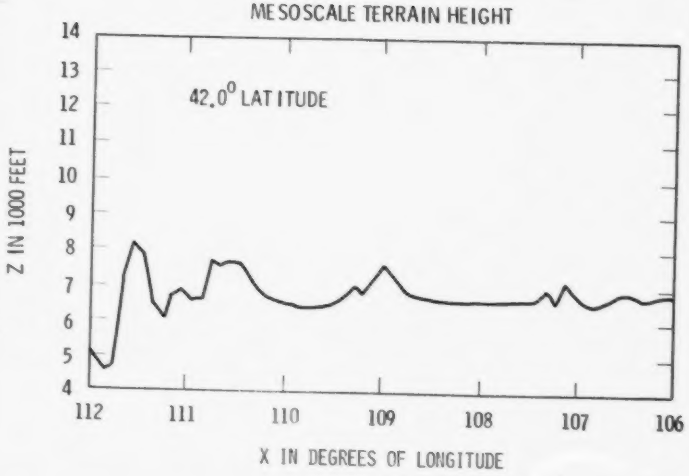


Figure C-11, continued.

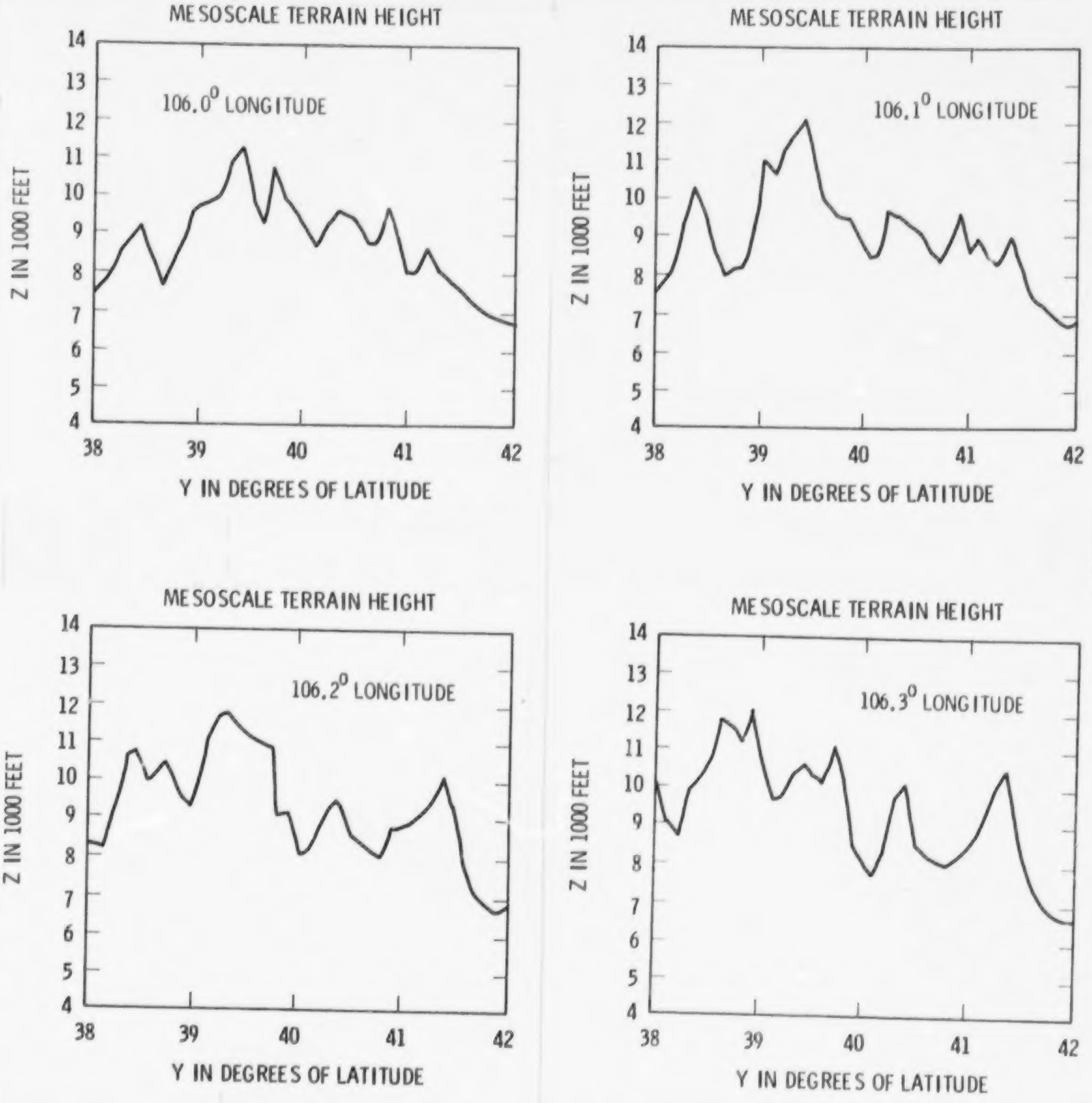


Figure C-12. Terrain profiles across the domain in Figure C-10, for every 1/10° of longitude and with a smoothing grid of 10 Km.

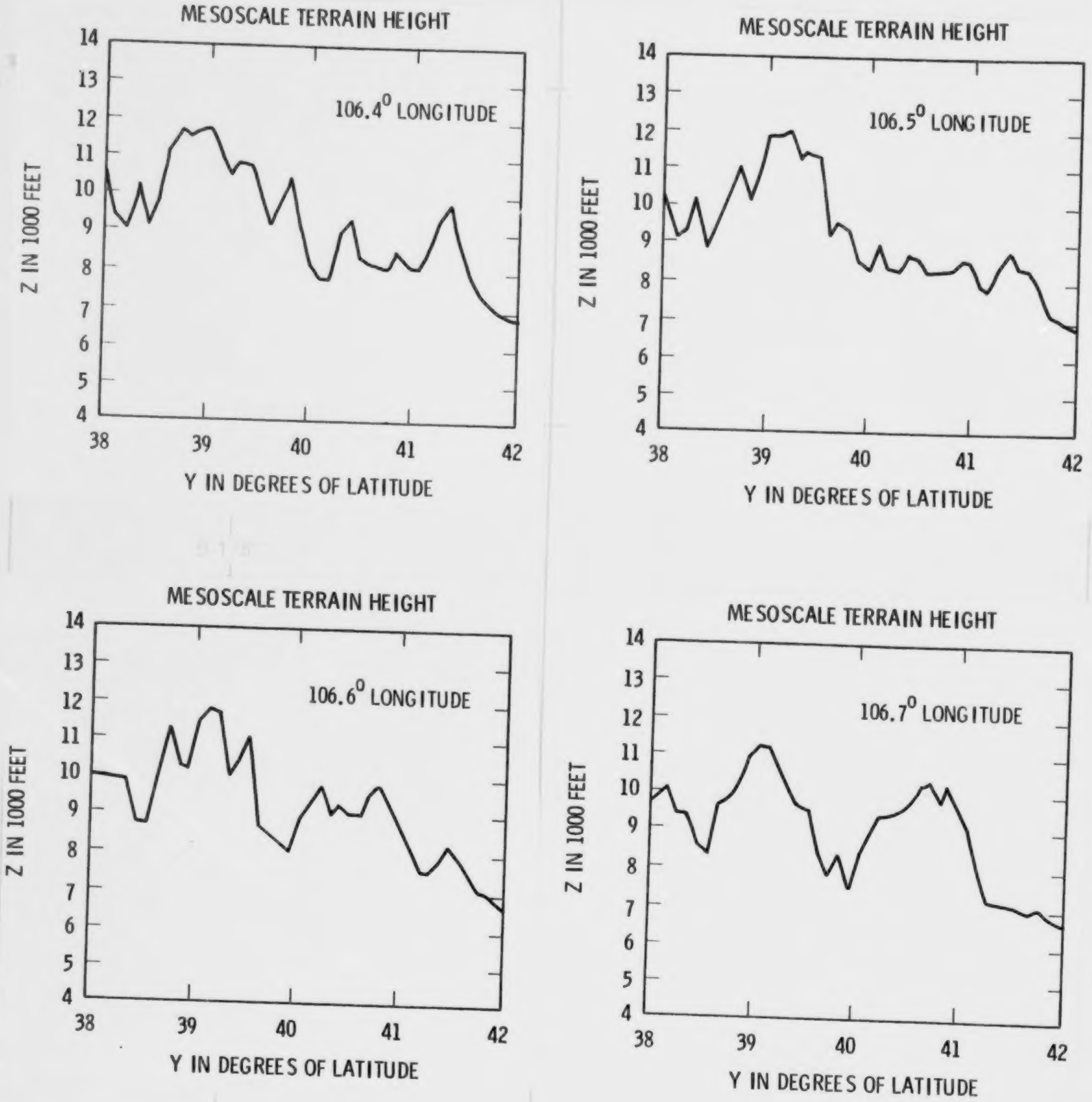


Figure C-12, continued.

EPA Form 2350-4 (4-80)
(PREVIOUSLY EIN. EPA FORM 297)
TYPING GUIDE SHEET

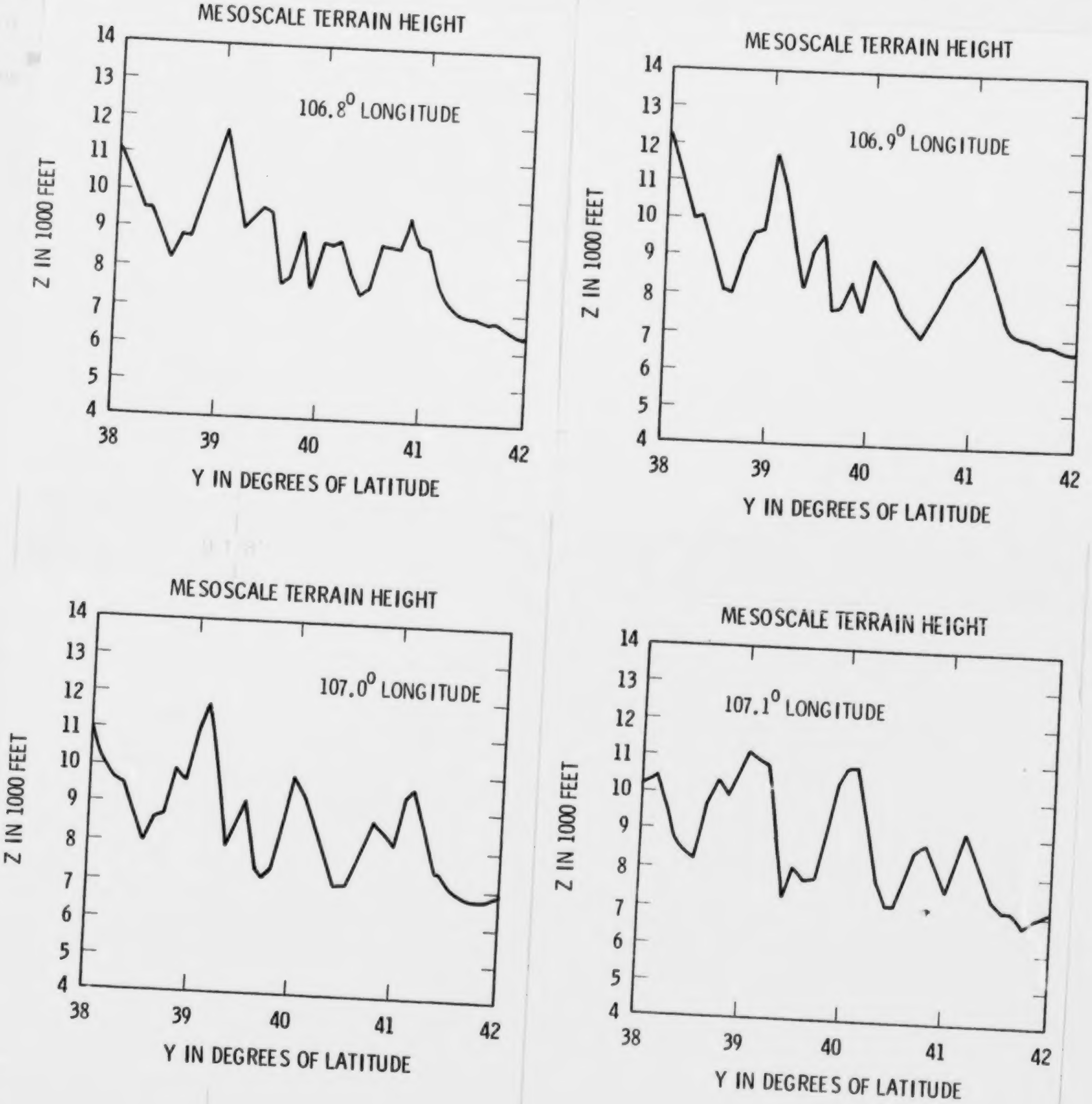


Figure C-12, continued.

TYPING GUIDE SHEET

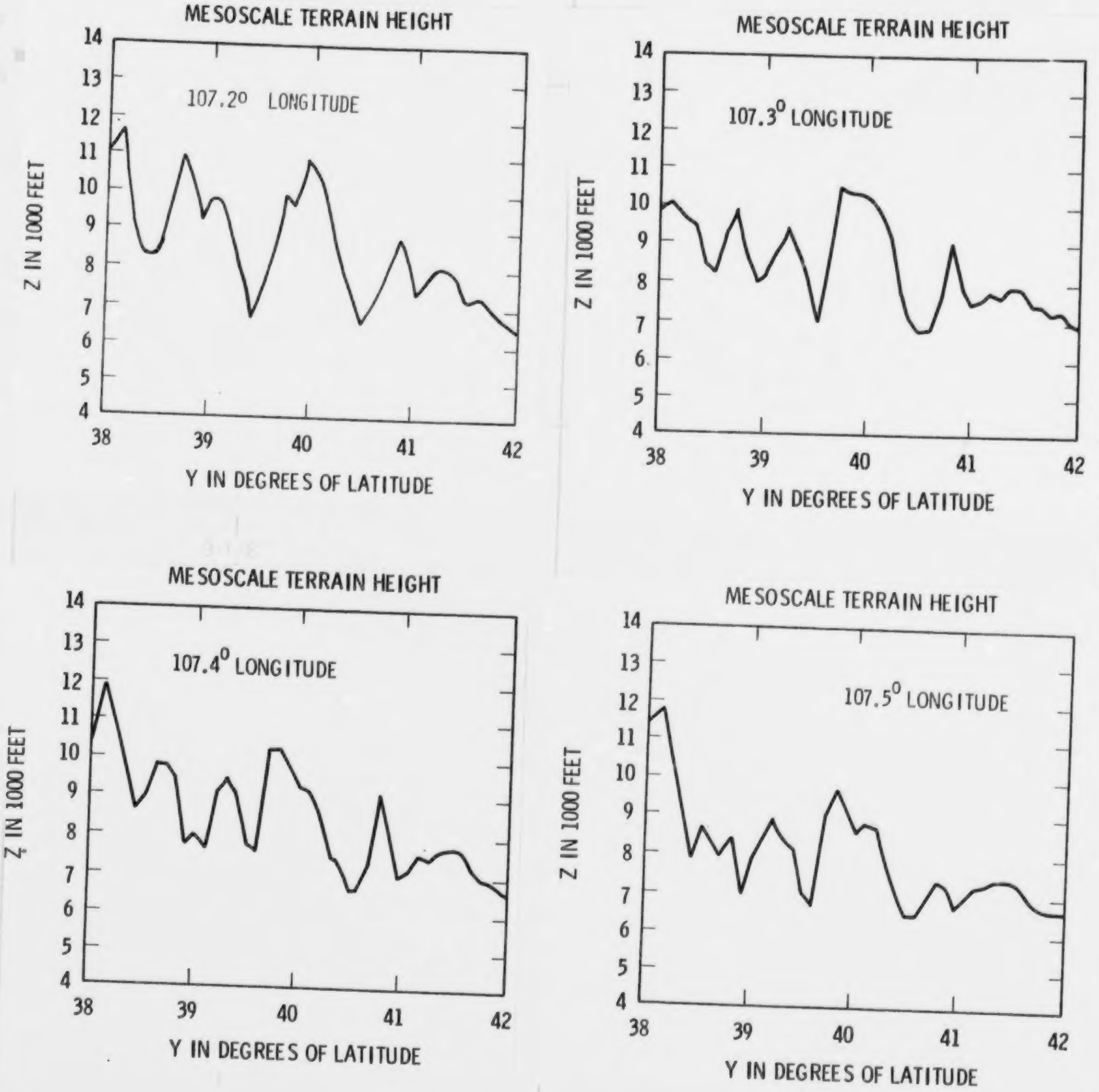


Figure C-12, continued.

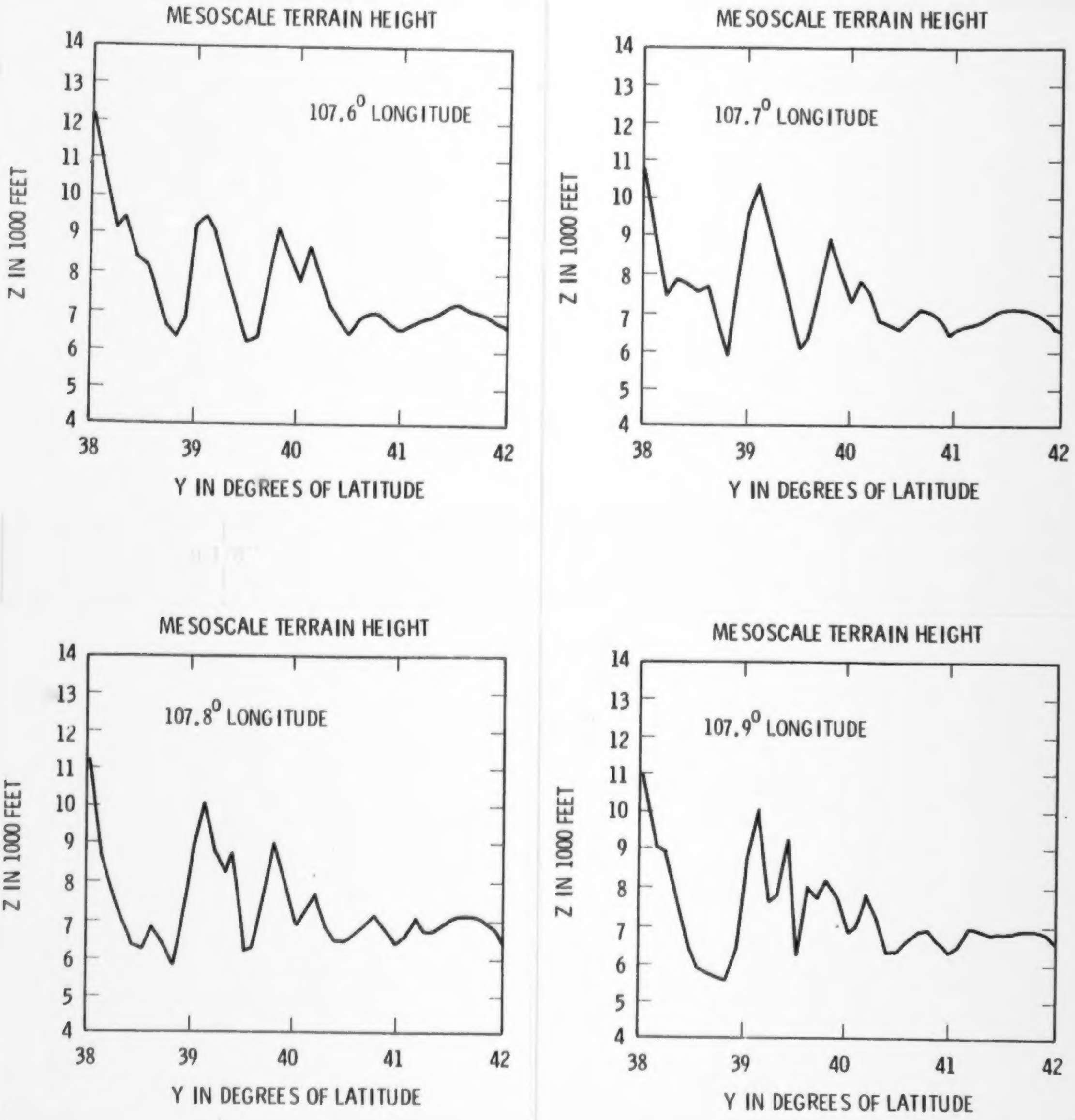


Figure C-12, continued.

EPA Form 2350-8 (4-80)
TYPING GUIDE SHEET

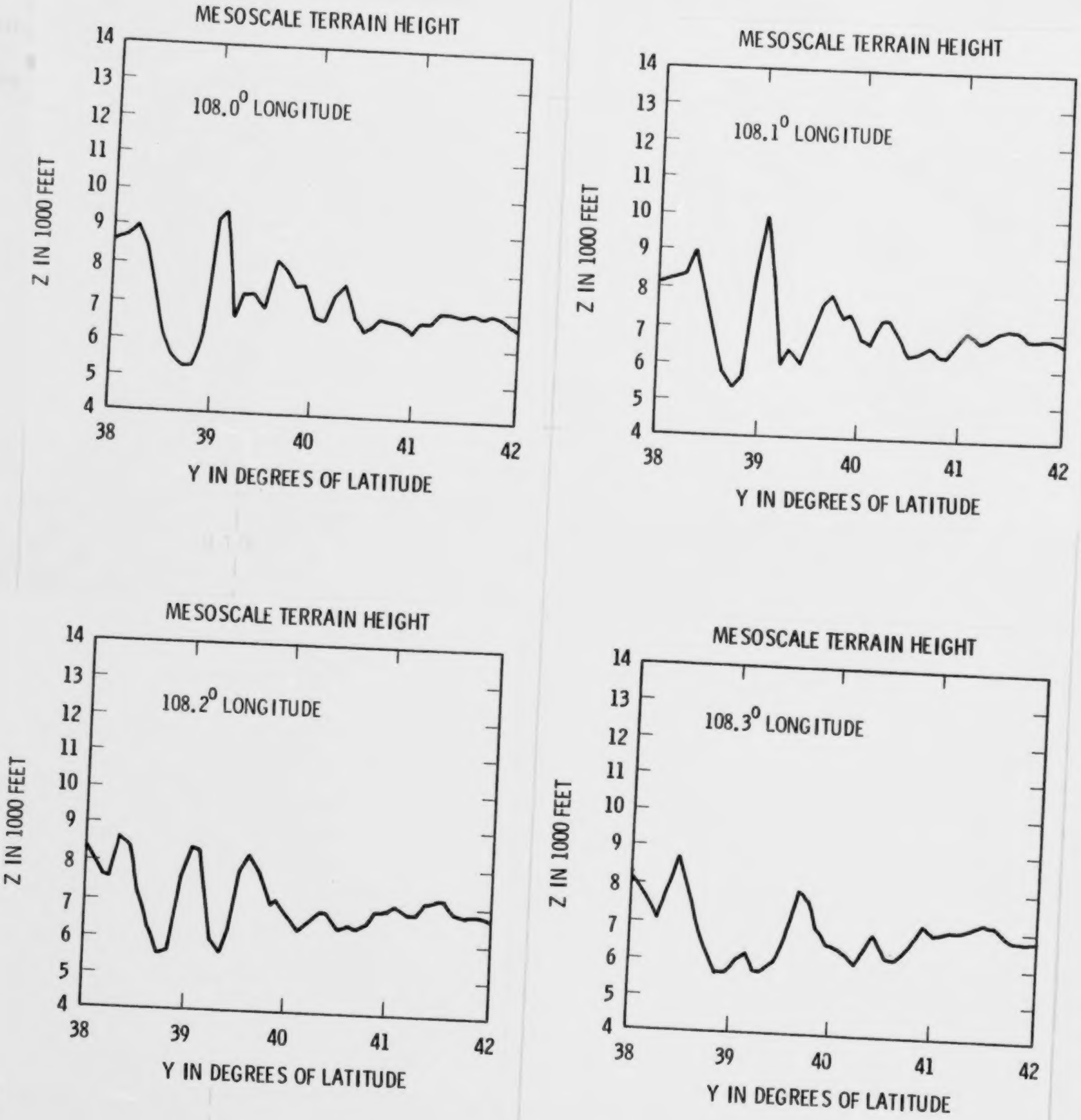


Figure C-12, continued.

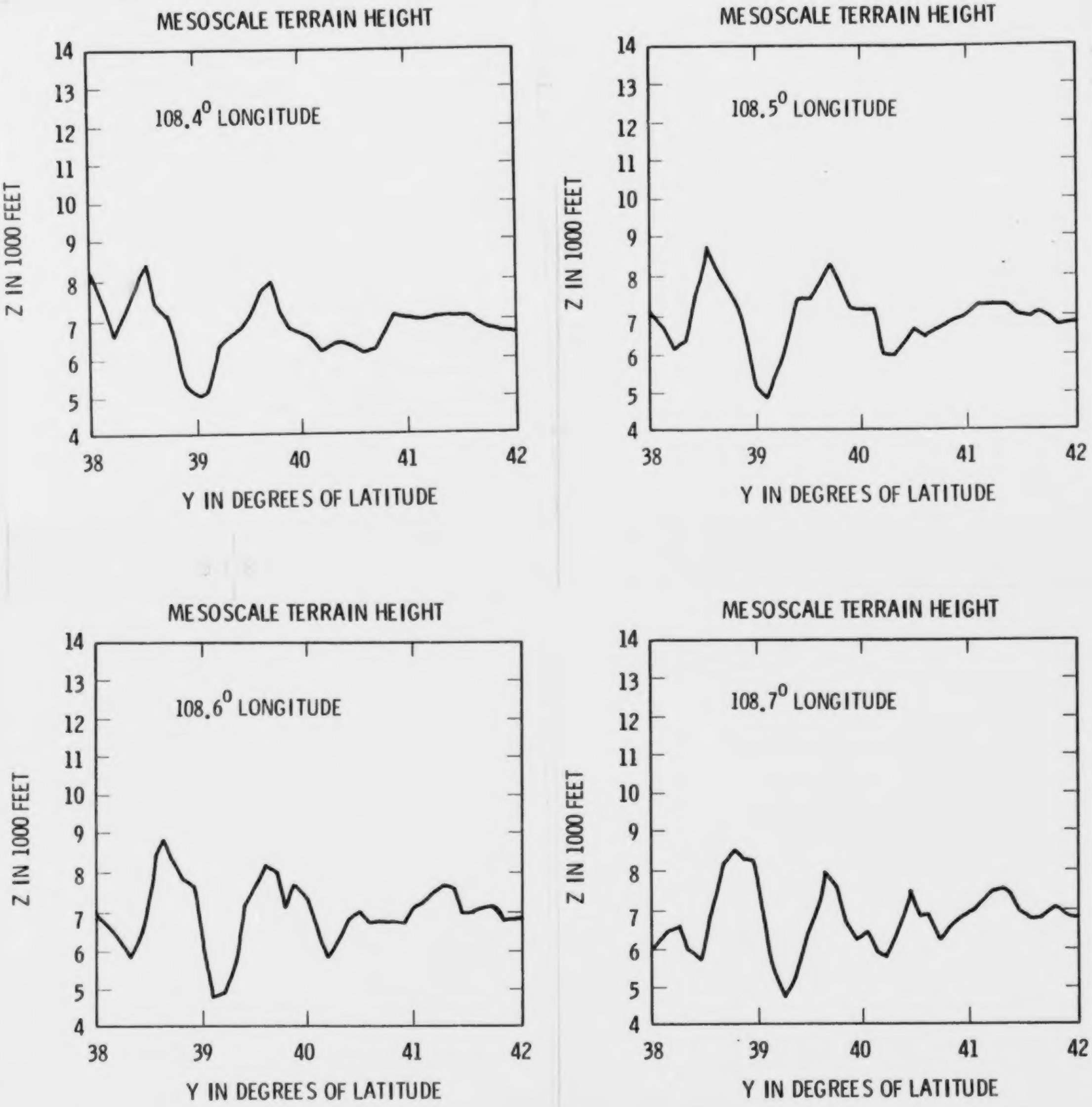


Figure C-12, continued.

EPA Form 2360-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 377)

TYPING GUIDE SHEET

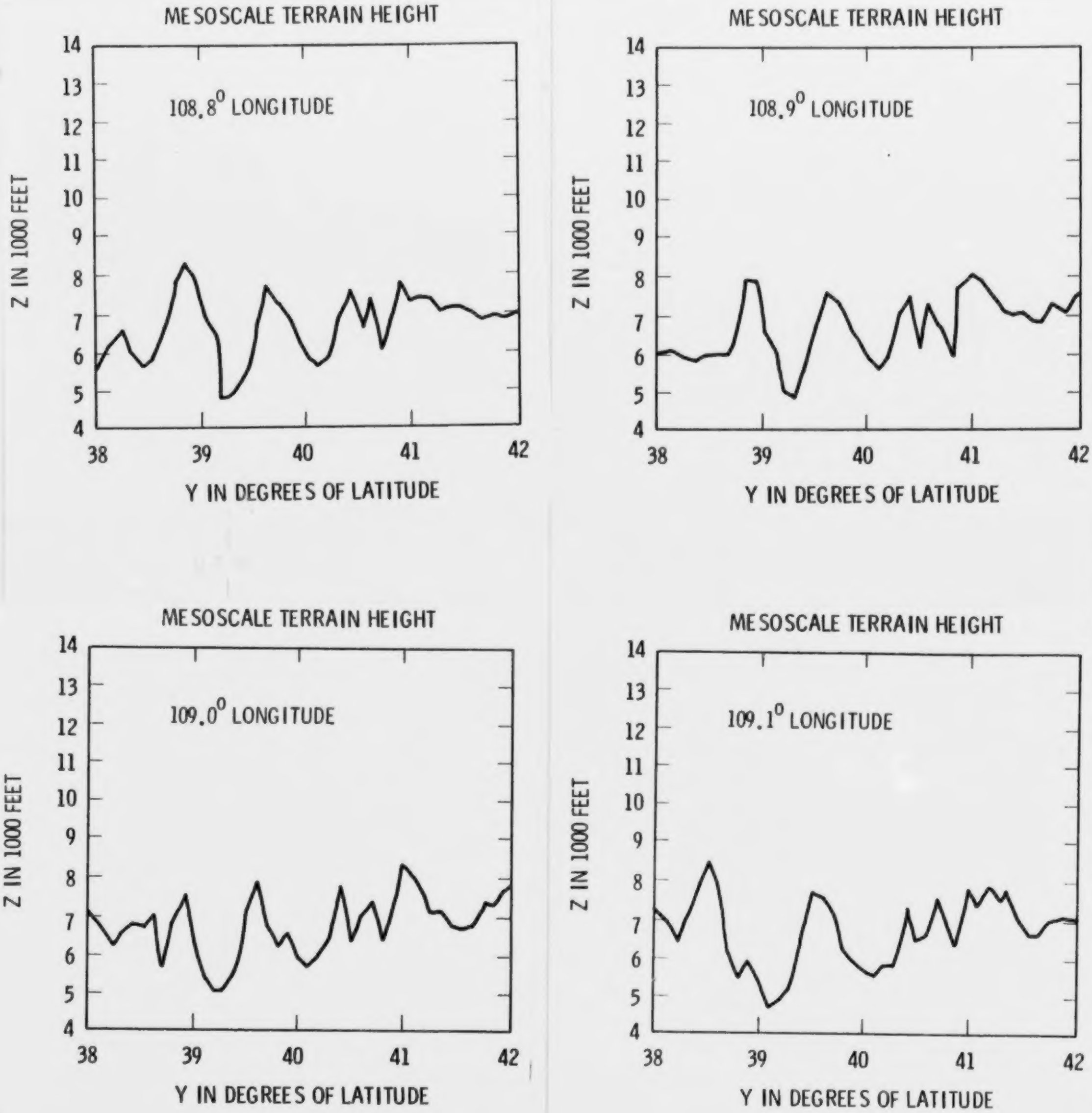


Figure C-12, continued.

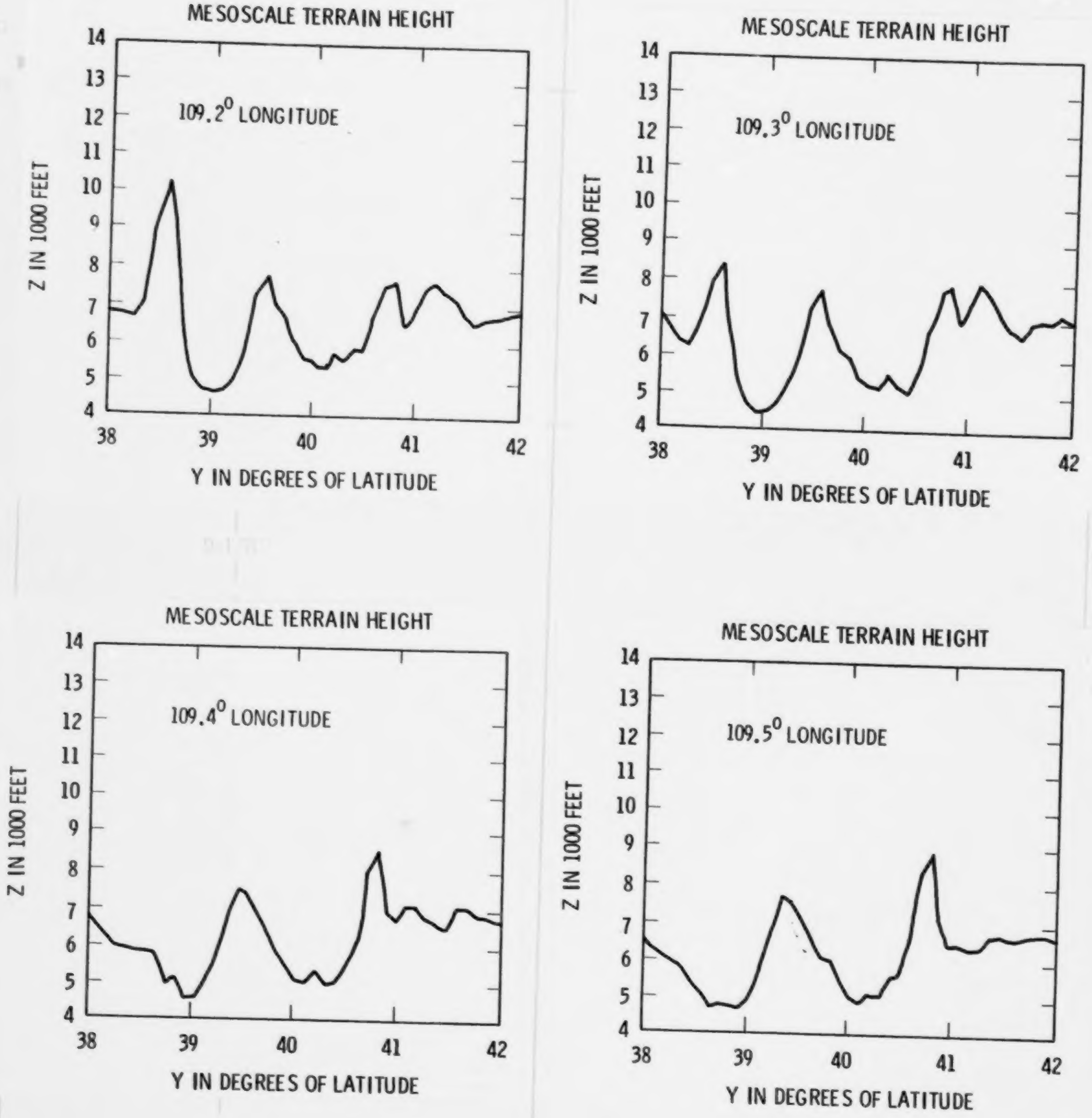


Figure C-12, continued.

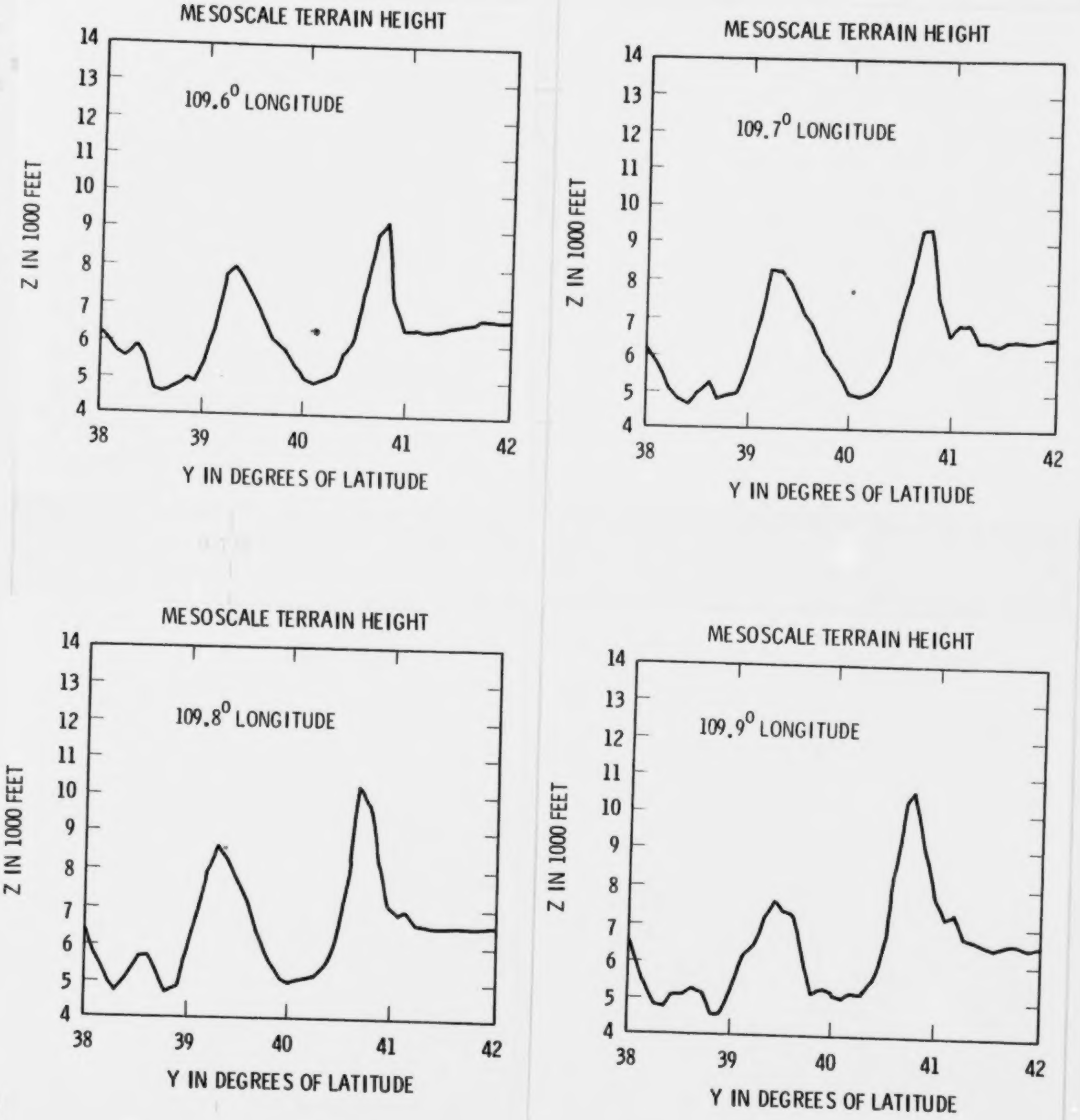


Figure C-12, continued.

EPA Form 2350-4 (4-80)
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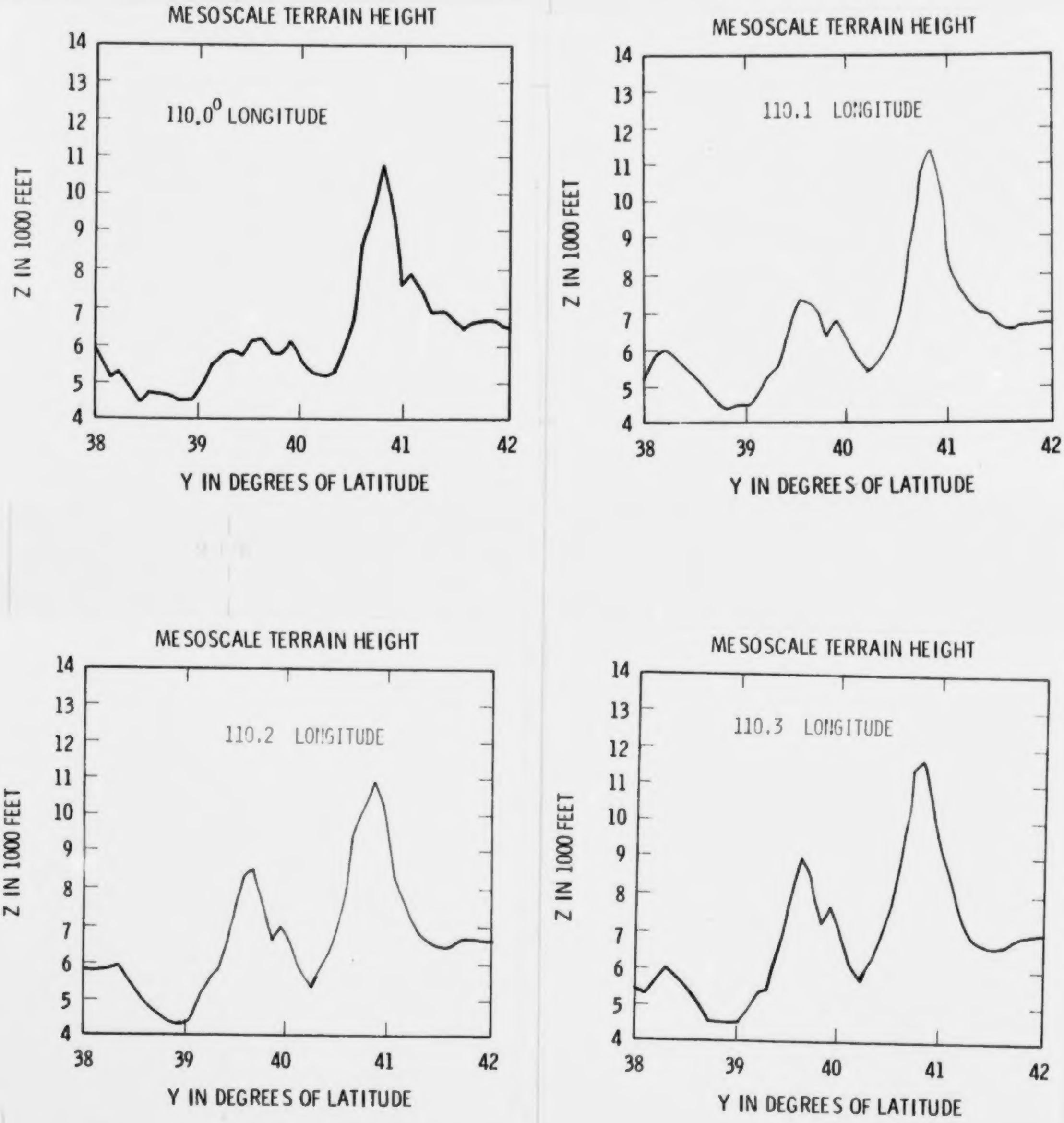

Figure C-12, continued.

EPA Form 2350-6 (4-80)
PAGE NUMBER
TYPING GUIDE SHEET

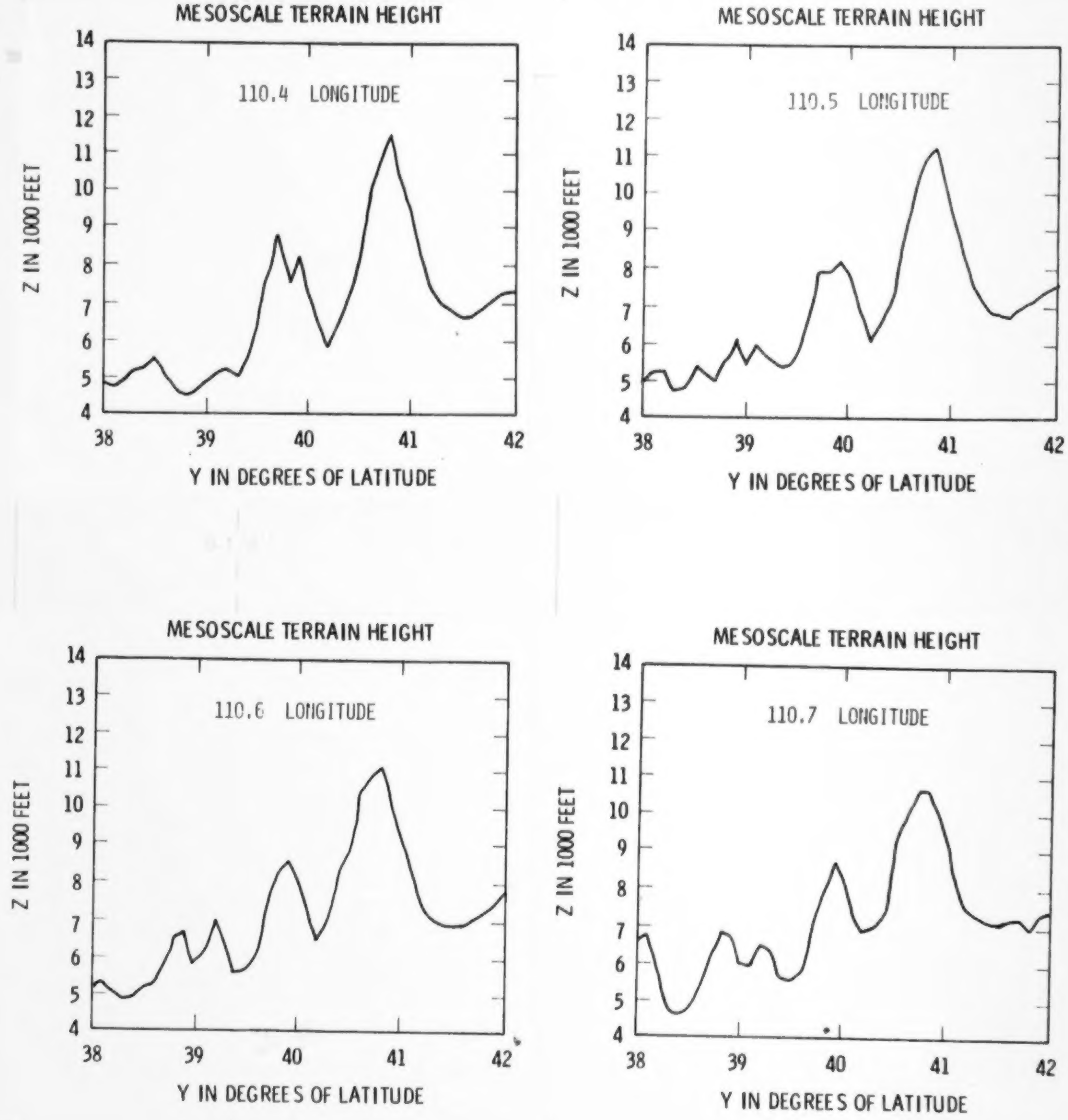

Figure C-12, continued.

TYPING GUIDE SHEET

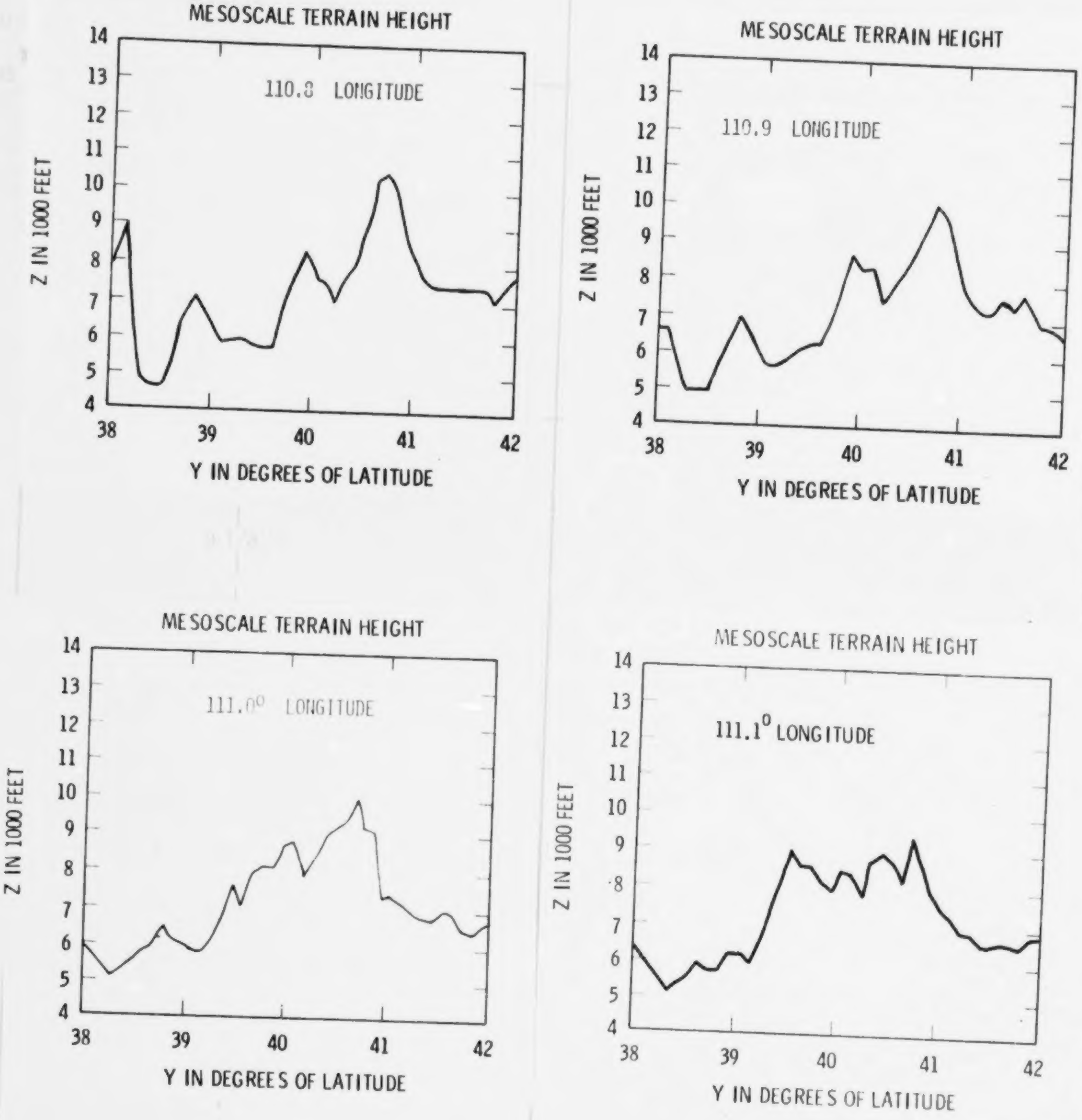

Figure C-12, continued.

EPA Form 2350-4 (6-80)
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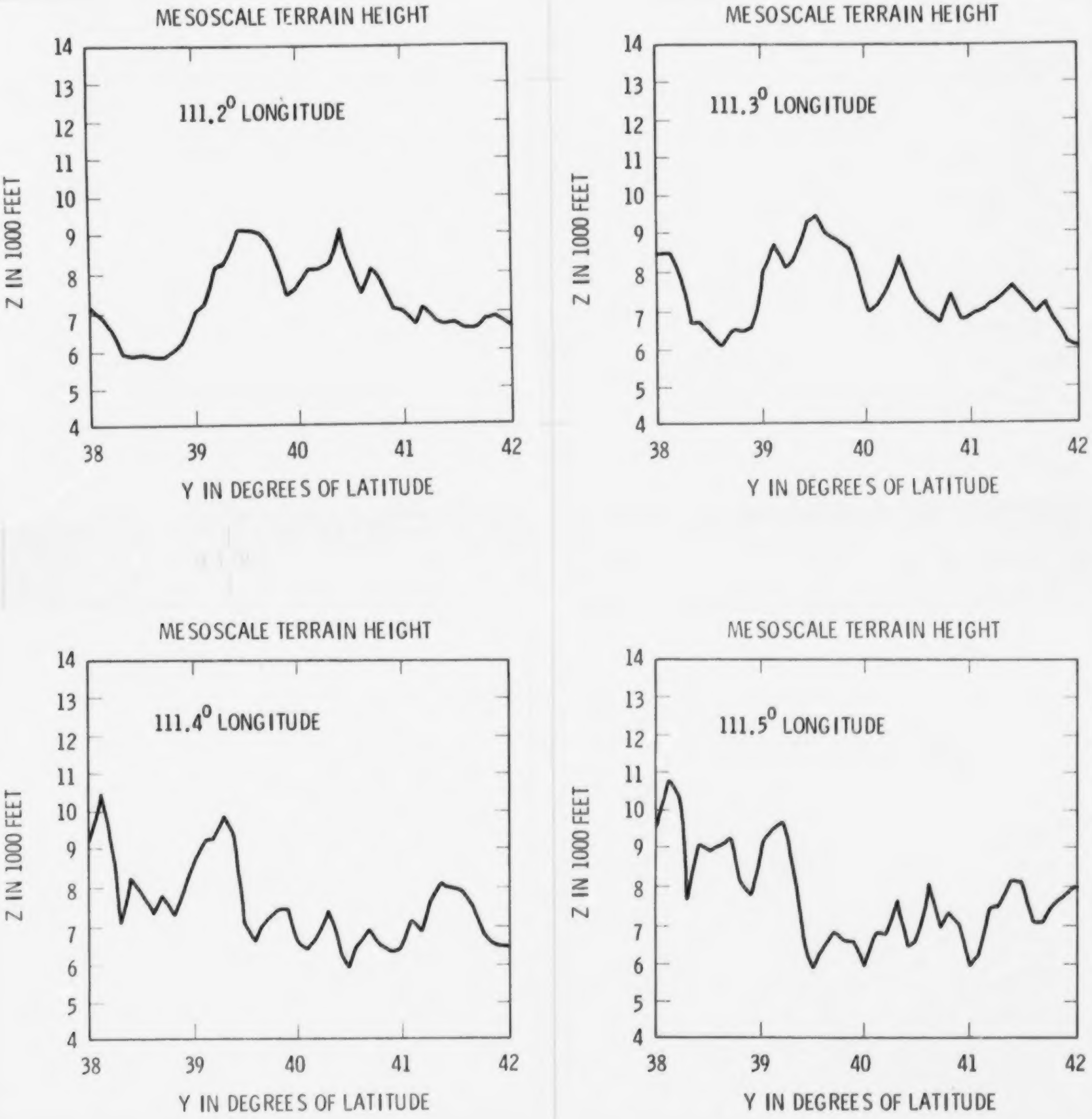

Figure C-12, continued.

EPA Form 2250-4 (4-80)

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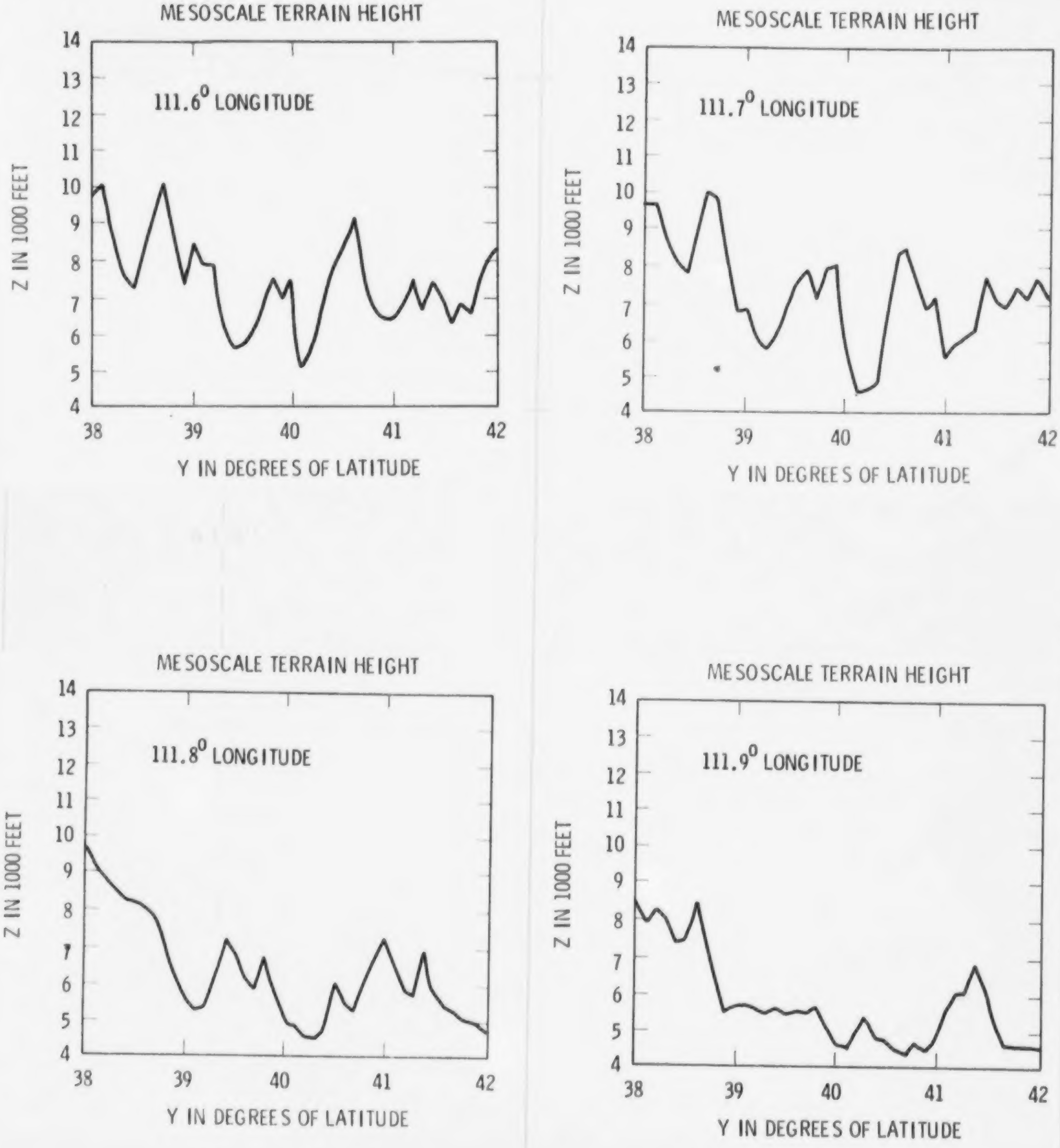

Figure C-12, continued.

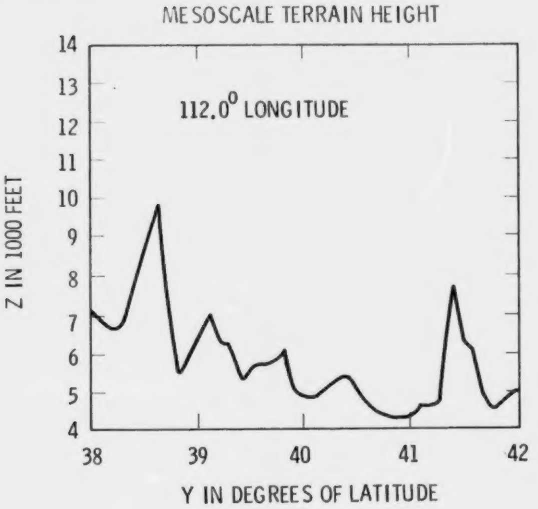

Figure C-12, continued.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 357)
TYPING GUIDE SHEET

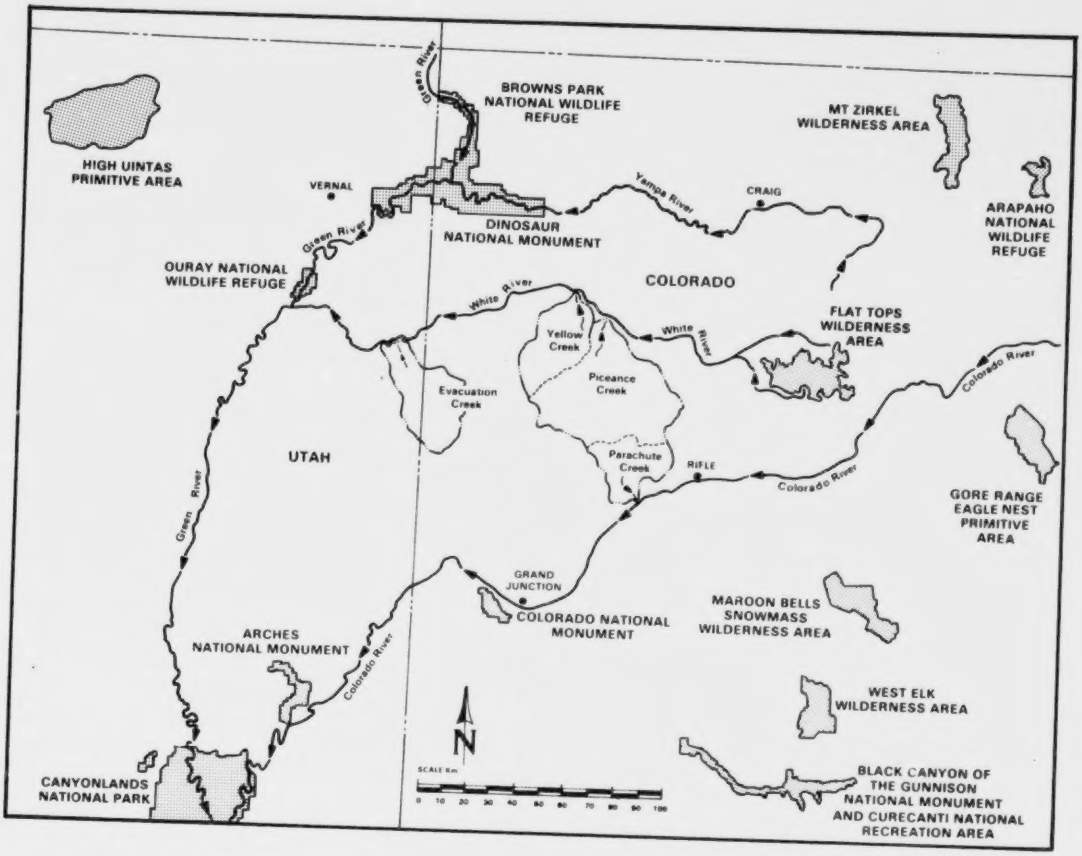
BROWNS PARK NATIONAL WILDLIFE REFUGE
Green River
HIGH UINTAS PRIMITIVE AREA
VERNAL
MT ZIRKEL WILDERNESS AREA
ARAPAHO NATIONAL WILDLIFE REFUGE
CRAIG
Yampa River
DINOSAUR NATIONAL MONUMENT
OURAY NATIONAL WILDLIFE REFUGE
Green River
COLORADO
White River
Yellow Creek
White River
FLAT TOPS WILDERNESS AREA
Piceance Creek
Evacuation Creek
Colorado River
UTAH
Parachute Creek
RIFLE
Colorado River
GORE RANGE EAGLE NEST PRIMITIVE AREA
Green River
GRAND JUNCTION
COLORADO NATIONAL MONUMENT
MAROON BELLS SNOWMASS WILDERNESS AREA
ARCHES NATIONAL MONUMENT
Colorado River
WEST ELK WILDERNESS AREA
N
SCALE Km
0 10 20 30 40 50 60 70 80 90 100
CANYONLANDS NATIONAL PARK
BLACK CANYON OF THE GUNNISON NATIONAL MONUMENT AND CURECANTI NATIONAL RECREATION AREA

Figure C-13. The oil shale areas of Utah and Colorado. Shown is a plan view of the Evacuation Creek and Piceance Basins, along with surrounding wilderness areas and river systems.

TYPING GUIDE SHEET

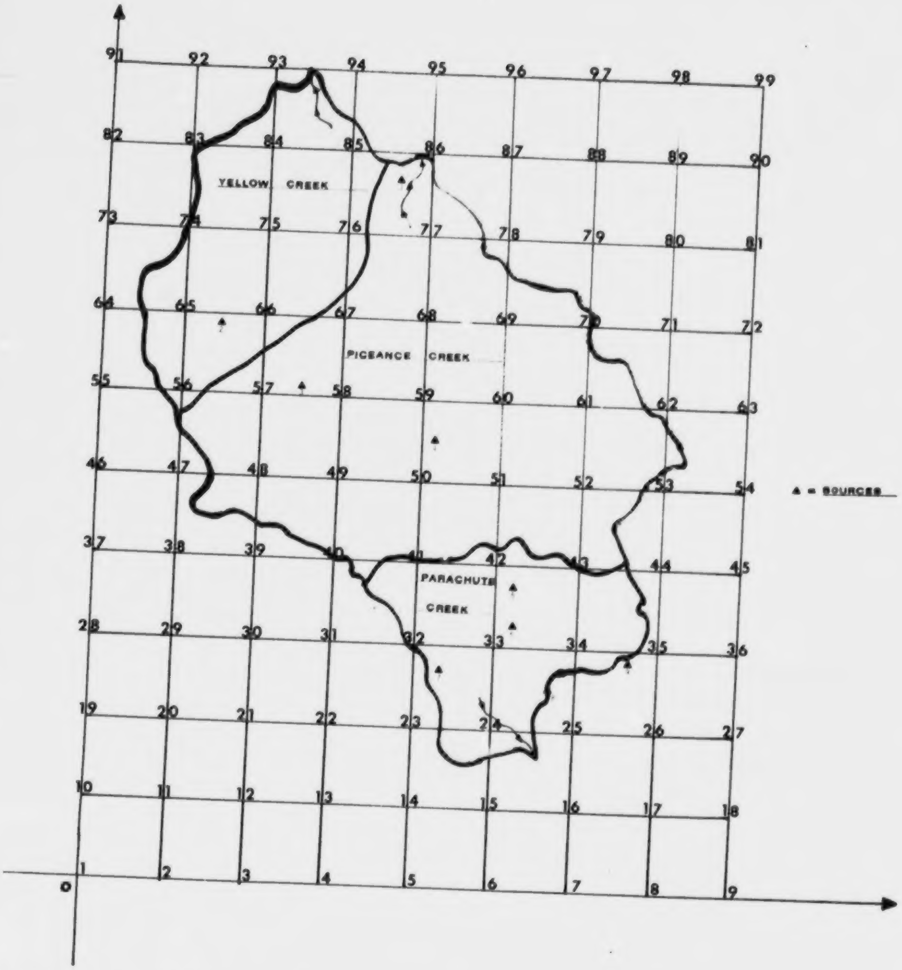
91 92 93 94 95 96 97 98 99
82 83 84 85 86 87 88 89 90
73 74 75 76 77 78 79 80 81
64 65 66 67 68 69 70 71 72
55 56 57 58 59 60 61 62 63
46 47 48 49 50 51 52 53 54
37 38 39 40 41 42 43 44 45
28 29 30 31 32 33 34 35 36
19 20 21 22 23 24 25 26 27
10 11 12 13 14 15 16 17 18
1 2 3 4 5 6 7 8 9
0
YELLOW CREEK
PICEANCE CREEK
PARACHUTE CREEK
▲ = SOURCES

Figure C-14. The Piceance Basin Oil Shale Area with a "modified", six-mile, township grid overlay. The Basin is subdivided into three watersheds (Yellow Creek, Piceance Creek, and Parachute Creek) and the oil-shale source locations are defined as: 1 = Superior, 2 = Tract C-a, 3 = Equity, 4 = Tract C-b, 5 = Colony, 6 = Long Ridge (Union), 7 = South Piceance Basin (Chevron), 8 = South Piceance Basin (Mobile), and 9 = Anvil Points.

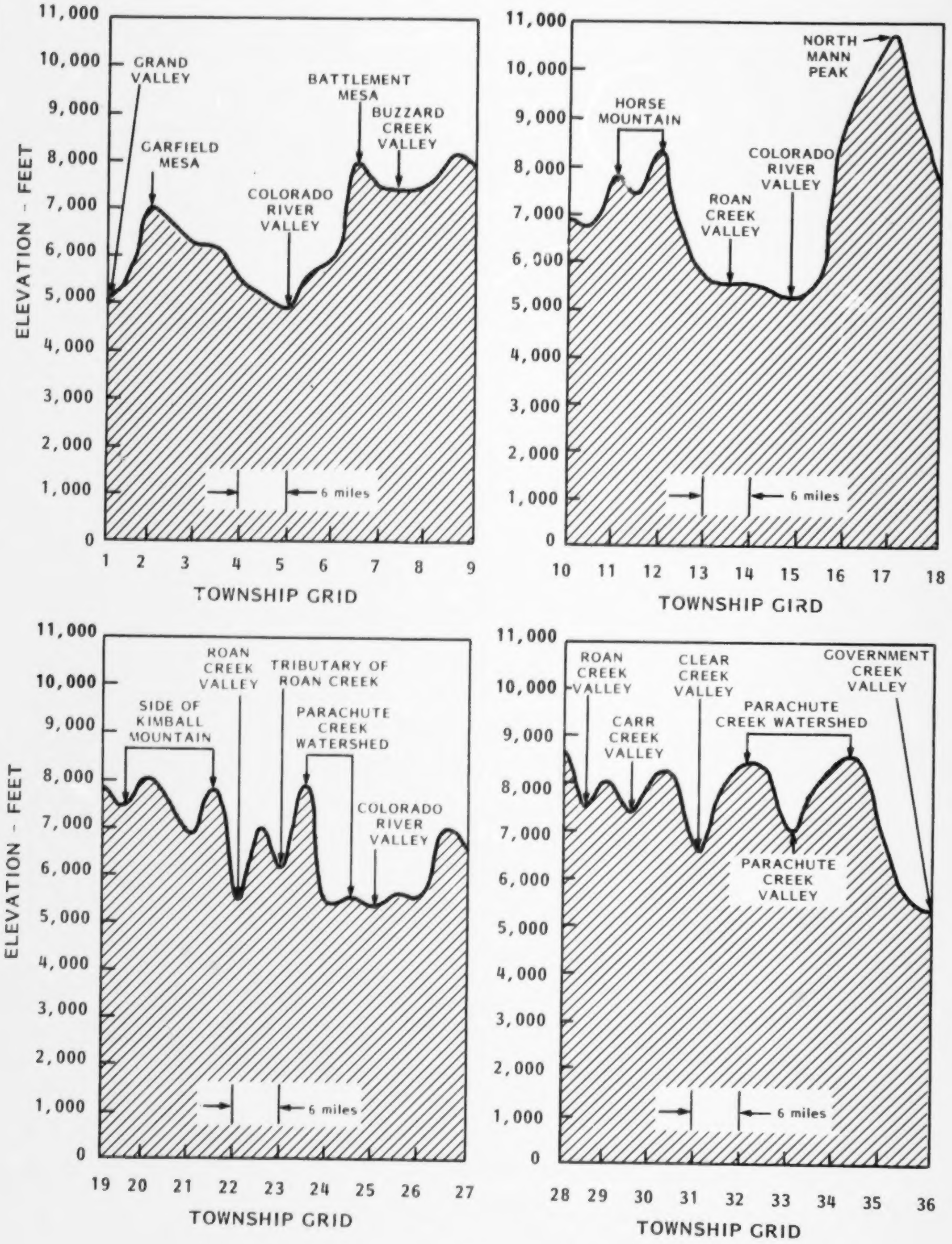

Figure C-15. Terrain profiles across the township grid shown in Figure C-14, with a smoothing grid of 3 Km.

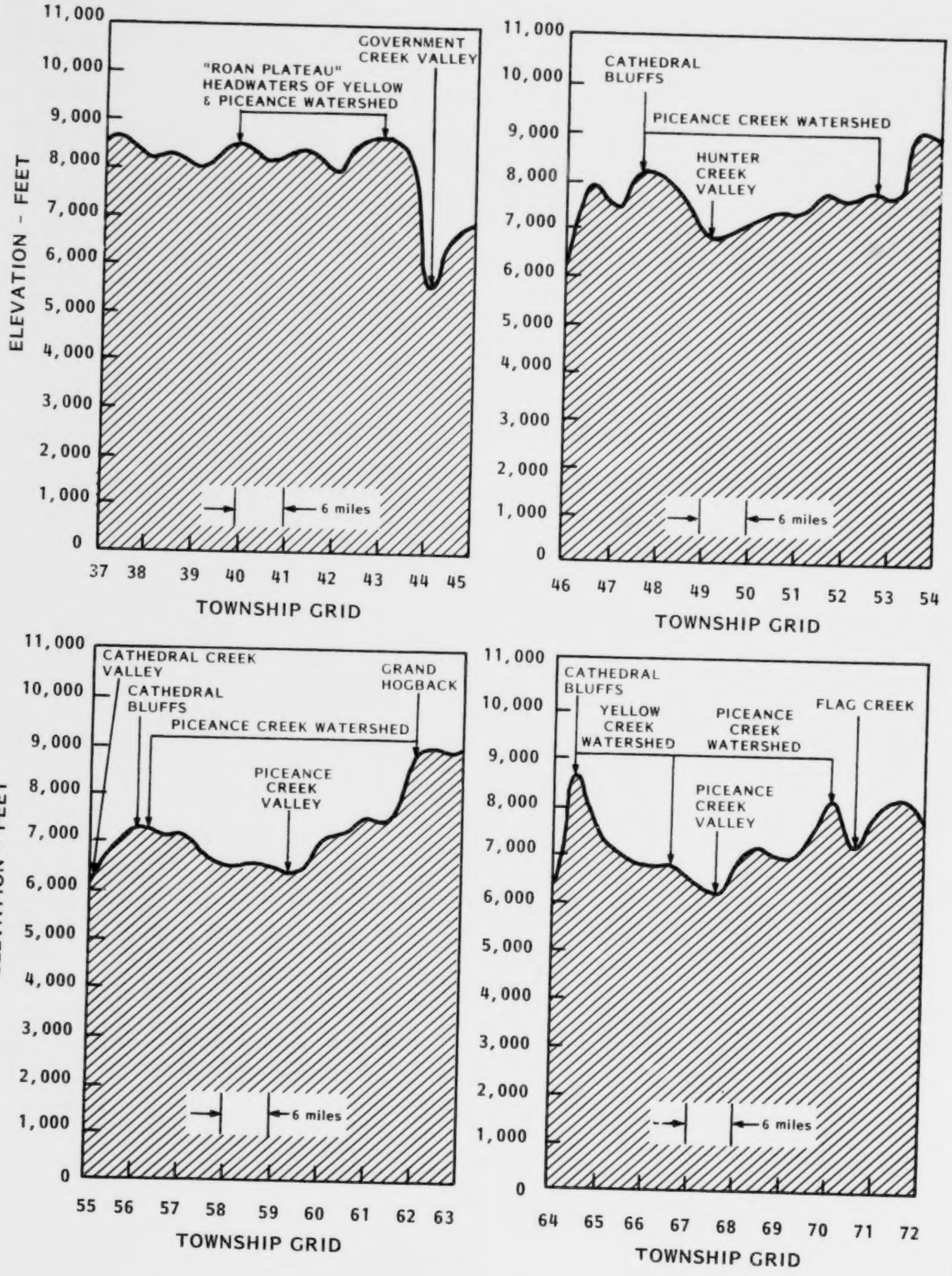

Figure C-15, continued.

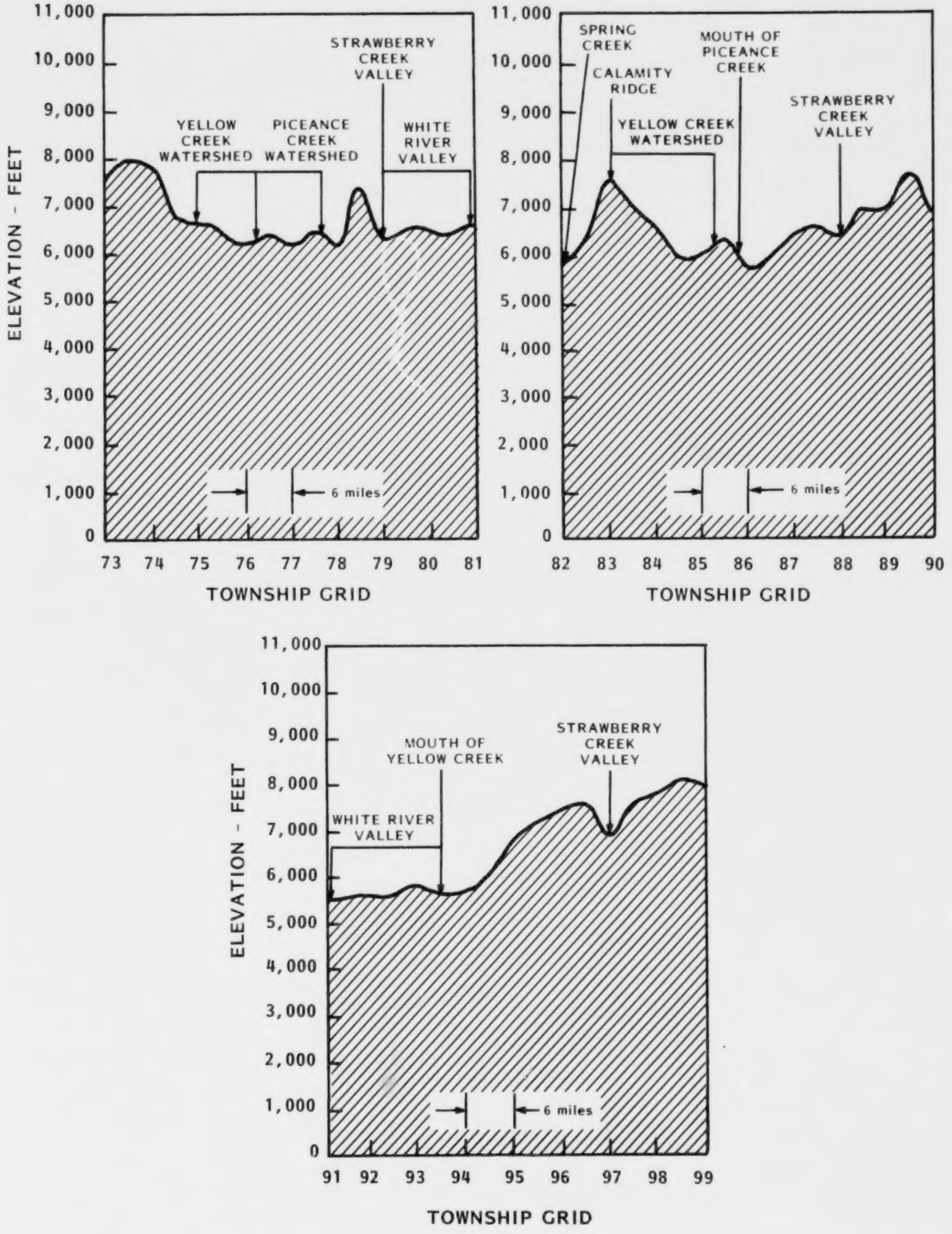

Figure C-15, continued.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET